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EDITORIAL

Apology is made for the late publication of this, the second and final part of Volume 7 of this *Journal*. The delay is due to a combination of circumstances. The writer took over from Lieut.-Col. Eaton the duties of Director of the Institute on 14th August, 1936, and his efficient handling of the reins of office was scarcely helped by the disastrous fire which destroyed one wing of the Institute little more than a month later; further reference to the effects of the fire is made below.

Fortunately the new buildings of the Institute were then nearly ready for occupation, but the preparations for the transfer of the Institute to them, and the removal itself—a sufficiently elaborate business even under normal conditions—were rendered additionally involved and urgent as a result of the fire.

The work of preparation of material for publication thus had to take second place to that involved in clearing up the confusion caused by the fire and in expediting the move to our new quarters. However, it is hoped to catch up the arrears of publication soon, the issue of the first part of Volume 8 being planned to take place not long after the present number.

THE FIRE AT THE INSTITUTE ON 24TH SEPTEMBER, 1936

The fire at the Institute originated in the testing section of the Chemical Division, from a cause which was not ascertainable though, by a process of elimination, an electric short-circuit is suspected to have been responsible.

Owing to the nature of the contents of the laboratories, and to the fact that the contents of a large new cylinder of oxygen were released by the fire at an early stage, the outbreak spread with amazing rapidity, and in less than an hour after the alarm (at 2.45 a.m.) the whole of the newer wing of the building, consisting of the Chemistry and Soils Divisions, was a raging furnace and practically gutted.

In consequence of the failure of the electric supply to the pump on which we depended for our supply of water, the Kuala Lumpur Fire Brigade, which arrived on the scene within ten minutes of receipt of the alarm, was powerless to suppress the fire, and all efforts were concentrated on preventing the spread of the fire to the rest of the building. Here we were helped by the thickness of the dividing wall, and the Fire Brigade, nobly assisted by a contingent from the P.W.D., and by a large number of Minimax fire extinguishers which were rushed to the scene by the Borneo Company, were able to check a threatened spread via the roof, and soon after dawn it was evident that, contrary to our worst fears, the rest of the building was saved.

Before this, however, and in spite of the darkness, relieved only by a few electric torches, the electric lighting not being available owing to the failure of the electric supply, the whole contents of the library (some 8,000 volumes), and all valuable records and apparatus in the rest of the building, had been removed to safety on the lawns outside, by many of the staff, assisted by about a hundred police and other willing helpers.

As soon as it was certain that further spread of the fire had been checked, everything was carried inside again, so that it was all once more under cover by 8.30 a.m., albeit in a state of such confusion that it was several weeks before everything was again sorted out and in its right place.

The material loss involved in the destruction of practically the whole contents of the Chemical and Soils Divisions amounted to over $80,000, the whole of which was covered by insurance. The most serious result was, of course, the loss of records.

The Chemical Division records lost related to work on various properties of rubber in connection with vulcanisation, ageing, plasticity, water absorption; methods of coagulation; soft rubber; rubber roadways; latex stability, latex concentration, and latex discoloration. The Soils Division lost records of tree measurements on experimental areas, soil profile descriptions and analyses, leaf analyses, meteorological data, and key to soil samples. In addition hundreds of samples of rubber, soils, and leaves were destroyed.

A part of the lost records had been written up and published, but in some cases this was not so. Thus Mr. Hastings' work on the variation in properties of rubber from different clones and in relation to different methods of treatment, involving the results of over three years' work, was just ready to be prepared for publication. Similarly with Mr. Hamilton's records of soil profiles and analyses, only a small part of which had been published.

However, valuable as these lost records were, and serious as is the delay involved in the need to repeat the more essential parts of the work, it was providential that the records of the Botanical Division, much of which related to new planting material —clones and seedlings—were unscathed, for a large part of this most important information would be quite irreplaceable if lost.

The New Buildings of the Institute at 3rd mile, Ampang Road

The need to order from home a complete new equipment of apparatus, chemicals and other materials for the Chemical and Soils Divisions delayed the occupation of the new buildings by several months. The transfer of the Institute to the new buildings was completed by the middle of March, 1937, and His Excellency the Governor of the Straits Settlements and High Commissioner for the Malay States, Sir Thomas Whitelegge Shenton Thomas, G.C.M.G., O.B.E., has consented to perform the opening ceremony on the 19th May. A description of the new buildings will appear in a later issue of this *Journal*.

This issue is wholly devoted to papers written by members of the Chemical Division. The next issue will consist of papers from the Botanical and Soils Divisions, whilst work of the Pathological Division will figure in a subsequent issue.

The Drying of Rubber

Rubber can be dried with a high degree of efficiency in a properly designed and managed smoke-house; there is, however, a considerable variation in the quality of the smoked sheet turned out from different estates, and in the drying efficiency of different smoke-houses. This connotes variation in the contribution which smoking makes to the total cost of production of raw rubber: moreover, the total variability in the quality of raw rubber—a variability which, even if not reflected in differences in grading and price, is a constant source of trouble to and complaints by the consumer—is to no small extent due to this cause.

Apart from individual preferences, often arbitrary, of buyers, for light or dark sheet, differences in the amount of smoking—as distinct from drying—correspond to differences in resistance to moulds and the like in transit and storage, and to differences in ageing properties, as illustrated by the work of Mr. Hastings, published in Vol. VI of this *Journal* p. 90.

The efficiency of modern smoke-houses is largely the result of empirical development, and little has been done in the scientific study of the drying of rubber. Further developments in the efficiency of drying and smoking, and in the standardisation of

smoked sheet, demands more scientific knowledge of the drying process. Work on this subject is therefore in progress at the Institute, in the Chemical Division, and forms the subject of a paper by Mr. J. H. Piddlesden in this issue.

There are three fairly clearly defined stages in the drying of wet sheet: first, the constant rate period when, owing to the general external wetness of the sheet, the rate is the same as that from a free water surface; then the intermediate period, or zone of unsaturated surface drying, when, owing to a continually increasing area of the sheet being free from superficial wetness, the rate of drying becomes gradually slower; and finally the period controlled by the rate of internal liquid diffusion, when the moisture to be removed is all inside the sheet and its rate of removal depends on the rate at which it can diffuse outwards to the surface.

In practice it is found that the first and second of these periods take up only a small proportion of the total drying time, and that the rate of drying in the third period determines, for practical purposes, the total drying time. Since in this third period the drying time is proportional to the square of the thickness of the sheet, it is obvious that one way of reducing the drying time is to make thinner sheet. For example, the time of drying of sheet one-tenth of an inch thick would be only about 64 per cent. of that of sheet one-eighth of an inch thick, other things being equal. It is also self-evident that the use of a higher temperature results in faster drying.

The practical difficulties of and objections to adopting these two means of increasing drying efficiency are discussed by Mr. Piddlesden, who concludes that, whilst improvements in the design, and in the thermal and drying efficiency are possible, the "automatic machine which can convert the wet rolled coagulum into dry smoked sheet in a few hours, will remain unrealised," so long as smoked sheet remains the main form in which dry rubber is exported.

"Subur" Type Smoke-houses

So-called because one of the first to be successfully developed was on Subur Estate, near Taiping, the Subur smoke-house possesses certain advantages over the other types. With improved conditions in the industry, many estates are now building or about to build new smoke-houses, and requests are constantly being received at the Institute for advice in their design.

The paper by Messrs. A. Moore and J. H. Piddlesden, of the Chemical Division of this Institute, which appears in this issue supplies enough information and detail about Subur smoke-houses

and their operation to enable Companies to decide on a design suitable for their individual needs, and to enable engineers and contractors to supply detailed plans and estimates. This paper will also be reprinted in pamphlet form.

A modification of the original type of Subur smoke-house with underground furnace has been developed in co-operation with the Institute, for use on land with a high water-table, or liable to flooding. This modified type, which is also described in the paper in question, has its furnace and flues above ground-level, and is sometimes known as the "Overground Subur," or, from the estate where it was successfully developed, the "Bernam-Perak" smoke-house.

One great advantage of the Subur type of smoke-house is that the rubber sheet need not be handled from the time it leaves the factory to the time it reaches the packing shed. It stays on the same trolleys throughout, the smoking chambers being on ground level. Moreover, smoking is practically continuous. The trolleys are pushed from one chamber to the next at suitable times, without any necessity to put out the fire and cool down the house. There are other advantages which are detailed in the paper, such as varying size, flexibility of design, low fire risk, low fuel cost, and moderate initial cost.

When properly operated the Subur smoke-house will dry normal sheet one-eighth to one-tenth of an inch in thickness in slightly less than four days, with a daily output of 1,800 or 3,600 lb. for the "single" or "double" sizes. During the last two years many smoke-houses of this type have been built.

Temporary Smoke-houses

A very cheap small smoke-house for use on small-holdings was described in this *Journal*, Vol. VI, p. 35, and a large number of such smoke-houses, costing from $4 to $8 each, with a capacity of about 80—100 lb. of dry rubber, are now in use on small-holdings throughout Malaya.

Estates sometimes need a temporary smoke-house, either following the destruction of their old one by fire, or where, on newly-opened estates, it is desired to defer the construction of a permanent smoke-house until the daily crop has reached a certain figure. The original small-holding smoke-house is too small for this purpose, but larger ones, of the same simple and inexpensive type, and a capacity of about 1,600 lb. dry sheet, have been found to work satisfactorily, costing $30 to $40 each, and lasting for a year or more.

Two such houses are in regular use at the Institute's Experiment Station, drying sheet of under one-eighth of an inch in

thickness in four to five days. A note by Mr. A. Moore, of the Chemical Division of this Institute, describing such a temporary smoke-house appears in this issue.

Centrifugal Concentration of Latex

The separation of latex into a cream and a skim fraction, in a similar fashion to that used for milk separation, is now a well-established commercial method of latex concentration, the machines used being essentially modifications of the centrifugal cream separator.

The temporary cessation of experimental work on this subject at the Institute provides a convenient occasion to summarise that work, and to indicate the essential or desirable features in the design and operation of such centrifugal latex concentrators. This is done in this issue in notes written by Mr. J. H. Piddlesden, of the Chemical Division.

Whilst the two machines used in the tests described could effect the necessary concentration, their practical usefulness was nullified by their liability to choke after a short time. This difficulty is believed to have been overcome in the machines in commercial use in Malaya under the protection of the Utermark patents.

Acid Preservation of Latex

Although acids are normally used to coagulate latex, there are zones of acid concentration—much above those used for coagulation—at which latex remains fluid. The possible commercial application of this fact, for special purposes, has been investigated in the Chemical Division of the Institute by Dr. Rhodes and Mr. Sekar in collaboration with the technical officers of the London Advisory Committee for Rubber Research. Unfortunately the detailed records of the work at the Institute were destroyed by fire, but the main findings are recorded in the note published in this issue. From the relatively large amounts of acid needed, and from the instability of the acid-preserved latex, it is unlikely that commercial applications are feasible.

Malayan Patents relating to Rubber

A list and reviews of such patents up to the end of 1932 were published in this *Journal* in 1933 and 1934 (Vol. V, pp 48 and 196). Further such patents up to the middle of September, 1936 are listed and abstracted in this issue, by Mr. Moore and Dr. Rhodes, of the Chemical Division of this Institute. It is indicative of the

orientation of the development of work on the processing and utilization of rubber that out of the 103 patents listed, practically half deal with the treatment and utilization of latex or with special forms of rubber (*e.g.* crumb; softened rubber).

Planting Holes and the Breeding of Mosquitoes

Attention is called to the note on p. 205, inserted at the request of the Malaria Advisory Board, which recapitulates the advice contained in the note on the same subject in the last issue.

Visitors to the Institute and to the Experiment Station

The attention of local readers is called to the notice at the beginning of this issue, in which certain modifications in the facilities for visits are embodied. It will assist in the arrangements for such visits if appointments are made through the Director and not with the Manager of the Experiment Station. There is of course no objection to the latter being consulted beforehand with a view to the reservation of a suitable date, but in such cases the intending visitor is asked to confirm the arrangement with the Director.

THE DRYING OF RUBBER

BY

J. H. PIDDLESDEN

Introduction

The design and operation of buildings for the drying and smoking of rubber has attracted considerable attention in the last few years. Several smoke-houses which shew improvements in the ease of handling the rubber, reductions in the time required to dry it, and a minimised risk of fire, have been designed. These advances have been largely empirical, and it was deemed advisable to carry out investigations into the fundamental mechanism involved, before attempting to study the effect of minor alterations in the technique of preparing and smoking sheet rubber.

(A) THEORY OF DRYING

The practice of drying varies widely according to the material which is being treated, but there are certain fundamental considerations which are applicable to all drying problems.

If a very wet solid is exposed to air, it immediately commences to lose water by evaporation. The rate at which this occurs depends upon the condition of the surrounding air, and the surface area exposed. While the surface remains completely wet the rate at which water is removed is independent of the moisture content of the solid. Thus, if the external conditions are maintained constant, drying proceeds at a constant rate, and while this persists the temperature of the solid surface will be the wet-bulb temperature of the air. This "constant rate period" as it is called continues until dry patches are formed on the surface. At this point, which is termed the "critical water content," the drying enters a so-called "falling rate period." This, in turn, may be divided into two portions. The first is the "zone of unsaturated surface drying," in which the external atmospheric conditions are still an important factor, but are modified by the consideration that, as drying proceeds the area of effective wet surface diminishes. The second portion of the falling rate period is the zone in which internal liquid diffusion takes control. At this stage the nature of the material being dried is of major importance, and the condition of the surrounding air has little or no effect. The rate-of-drying curve is thus divided into at least three portions, each controlled by different sets of variables.

These are:—

(i) *The Constant Rate Period*

This, as was stated above, obtains while the surface remains uniformly wet. The rate remains constant only if certain "drying conditions" are maintained constant. A study of these will indicate the method for obtaining the best rate during this phase of the drying. Evaporation from the free liquid surface at the wet surface of a solid is analogous to that which occurs at an air-liquid interface whenever the vapour pressure in the air is below that of the liquid, at the temperature of the surface, and is due to this difference. The evaporation of the liquid abstracts heat from the system.

The first objective, if a high drying rate is required, must be to establish the maximum possible vapour pressure difference between the surface of the wet body, and the air in contact with it. Here a further factor is introduced. The layer of air in contact with the surface soon becomes saturated with moisture, and evaporation is therefore limited by the rate at which the moisture can diffuse through this layer. This in turn depends upon the thickness of the layer, which may readily be reduced by increasing the air velocity across the surface.

The partial pressure of water vapour in the air must be as far below the saturation pressure as possible. The ratio between these two values is expressed as the percentage relative humidity. As the capacity of air for carrying water vapour increases very rapidly with increase of temperature, this provides a very simple method of reducing the relative humidity. For example, air containing .02 lb. water vapour per lb. of dry air (a normal figure for Malaya) is saturated at approximately 76°F and if cooled below this point will deposit dew; whereas this same mixture raised to 130°F has a relative humidity of about 22 per cent, and will absorb nearly 400 per cent more water before condensation occurs. Thus for rapid evaporation, not only must the air velocity be high, but the relative humidity must be low. These conditions may be achieved by using a constant stream of fresh air at high temperature. The surface area must also be as large as possible. Finally, since the process absorbs heat, a continuous supply of heat must be maintained in order to prevent the temperature of the whole system from falling.

(ii) *Zone of Unsaturated Surface Drying*

The zone of unsaturated surface drying constitutes the first portion of the falling rate period. It commences when dry patches begin to occur on the surface, and continues until the rate of

diffusion becomes the controlling factor. The rate of drying at this stage is also controlled by evaporation. The variables affecting this rate are therefore the same as those given above, except that in this case the wet surface area is diminishing as the drying proceeds. During this phase the area of wet surface, and consequently the drying rate, usually decrease in approximately direct proportion with the moisture content of the solid.

(iii) *Period Controlled by the Rate of Internal Liquid Diffusion*

The rate of diffusion of moisture from the interior to the surface of a wet slab decreases with the water content of the material. A second "critical point" therefore occurs when the rate of diffusion can no longer keep pace with the rate of evaporation from the surface. When the moisture content is below this critical value the rate of diffusion controls the rate of drying. The diffusion of liquids through solids follows closely laws governing the diffusion of heat. The rate of drying under these conditions may therefore be expressed as a Fourier series, based on the general equation[1]

$$\frac{dM}{dT} = k\frac{d^2 M}{d s^2}$$

where M is the free moisture content *i.e.* the total moisture minus the equilibrium moisture

T is the time

s is the thickness of the material

k is the diffusion factor.

The value of the diffusion factor (k) is determined by the permeability of the particular substance being dried, and by the temperature at which the drying is carried out. The time required for drying may be reduced by increasing the temperature, or by so modifying the material that it is more permeable to water. Either of these expedients will increase the value of the diffusion factor (k). It can also be shewn[2] from the theoretical equation that the drying time is proportional to the thickness squared.

(B) APPLICATION TO RUBBER OF THE THEORY OF DRYING

It will be seen from the foregoing that for rapid drying the sheet rubber should be as thin and porous as possible, high temperatures should be used throughout and, in the early stages, high air velocity should be advantageous. There are obviously practical limitations to the application of these conditions. Unduly high temperatures will damage the sheet by blistering. If the sheet is machined too thin, the cost of machining, the space required in

the smoke-house, and the difficulties in handling are all increased. Finally, to use high air velocities, and at the same time to maintain an adequately high temperature, would necessitate a large expenditure on smoke-house fuel, unless some mechanical system for the recirculation of air were used. The first object of our experiments was therefore to determine at what stage diffusion became the controlling factor in the rate of drying, since prior to this the velocity and humidity of the air are important factors, whereas afterwards the sheet thickness becomes of major importance.

Van Harpen[3] found for certain rubber samples, that the total drying time for each was proportional to the square of its thickness. From the foregoing it will be seen that this implies that the whole drying period is controlled by the rate of diffusion, and that the initial constant rate period during which ventilation is the important factor occupies a negligible proportion of the total time.

Experimental

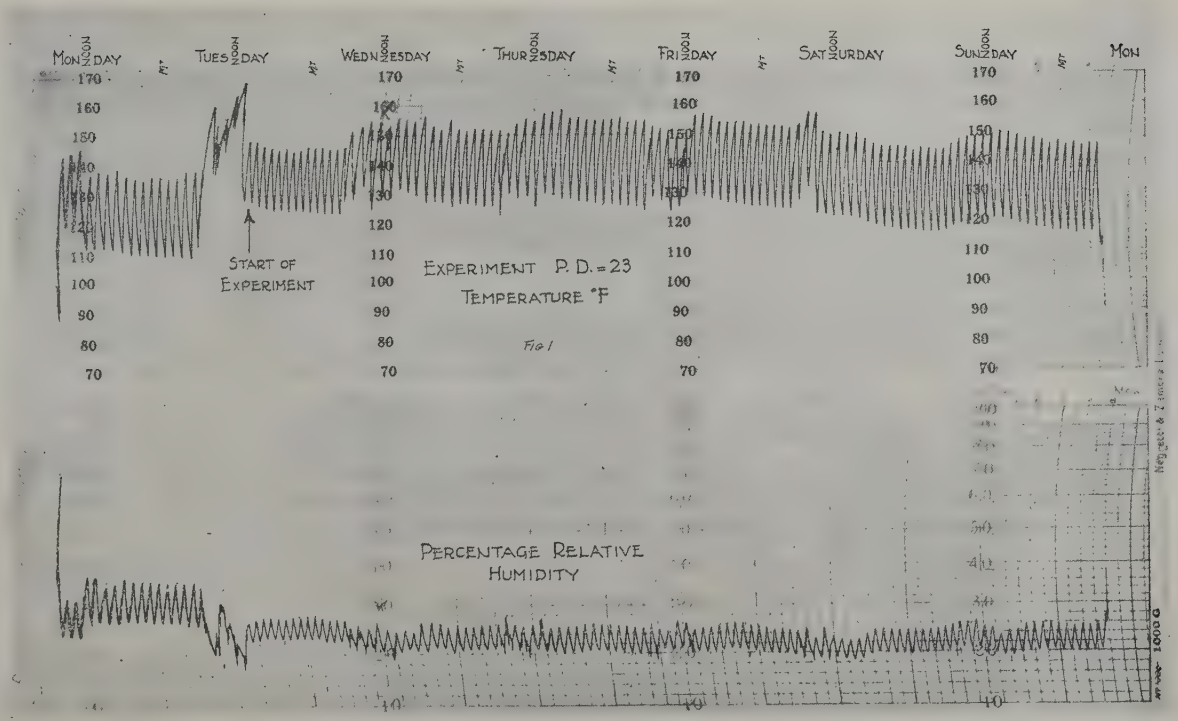
A few rough preliminary trials soon indicated that the last traces of water were difficult to remove from rubber. Thus, if small samples of rubber were used, extremely accurate weighing was necessary, to follow the drying in the later stages. Such weighings could not be carried out rapidly, since it was first necessary to cool the sample, and the delay so caused made the time and temperature records inaccurate.

To overcome these objections an attempt was made to construct a recording weighing machine, which could be placed in the drying cabinet. Sufficient accuracy could not be achieved by this device, and it had the further objection that the number of samples which could be handled simultaneously was limited by the number of machines.

It was therefore decided to use full-sized pan sheets, which could be weighed very rapidly to the nearest 0.1 gm. on a decimal balance. It was soon found that the use of a marking roll introduced variability owing to the different depth of impression made on sheets of different thicknesses.

As a result of these preliminary trials the following procedure was adopted. Latex was coagulated in pans each holding one gallon of liquid containing 15 per cent of dry rubber. The coagulum was machined next morning to the required thicknesses through rolls with calibrated adjusting screws, two sheets being rolled at each setting. After varying periods of soaking and dripping, the sheets were dried in a thermostatically-controlled, electrically-heated drying cupboard. The temperature and humidity

FIGURE 1


MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
SUNDAY
MON
NOON
MT
START OF EXPERIMENT
EXPERIMENT P. D. = 23
TEMPERATURE °F
Fig 1
PERCENTAGE RELATIVE HUMIDITY

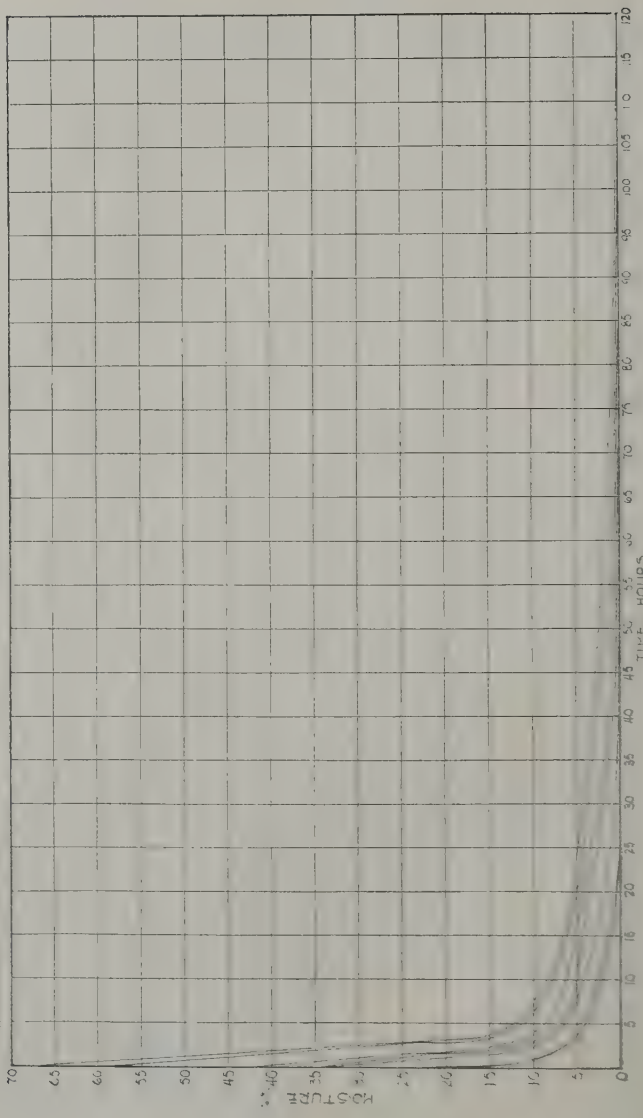
of the air inside were recorded automatically, and the sheets were removed and weighed at intervals until dry. Dryness was assumed when there were no longer any opaque patches in the sheet.

Owing to the intermittent method of weighing, the actual point at which the rubber became dry could not be determined very accurately. Overnight an interval of 18 hours elapsed between weighings. The rate of drying was however very slow during the final stages and the curve of percentage moisture plotted against time was very flat and approximated closely to a straight line. It was also frequently found that there were small inequalities in the sheet and that very small wet patches sometimes persisted for a considerable time after the rest of the sheet was dry. Therefore, although drying was continued until complete transparency was achieved, and this was regarded as the dry weight, the end point of the drying was taken to be the point at which the rubber contained 0.1 per cent moisture and the drying time was obtained by extrapolation or interpolation to this point, from the few weighings taken on each sheet immediately before dryness was perceived. This procedure largely eliminated the errors due to very small wet patches, and to the possibility that complete transparency was not noted until a few hours after it had occurred.

Since the heating load was heavy and no relay was available the thermostatic control was rather insensitive and the temperature and humidity charts obtained were similar to those shewn in Fig. 1. The average temperature and humidity ruling throughout each experiment was obtained by summing all the points of inflexion and calculating the mean.

For each experiment, curves of moisture-content against time were plotted, and in each case the lower portion was replotted on a magnified moisture-content scale. A typical example is shewn in Figs. 2 and 3. As was predicted, the first portion of the curve was very steep and practically straight, but by the time that 10 per cent moisture-content was reached, diffusion appeared to have become the controlling factor, and this figure was therefore taken as the second critical moisture-content. A careful study of all the curves indicated that this was a good average value. It was immediately obvious from the curves that this diffusion portion of the drying occupied the greater part of the total time involved.

FIGURE 2



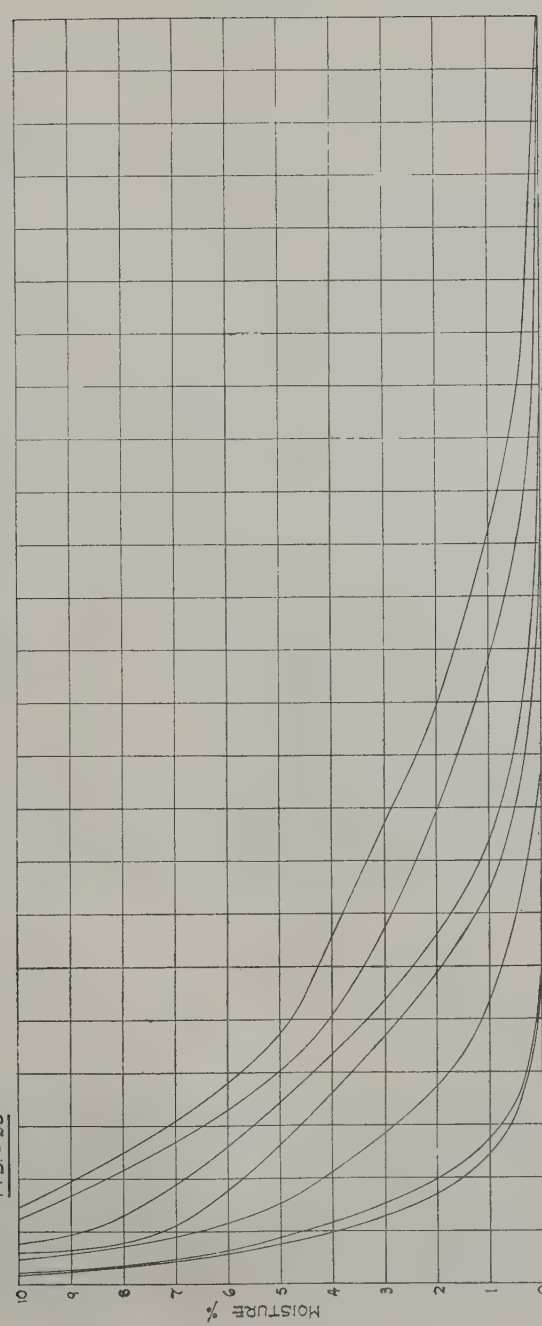
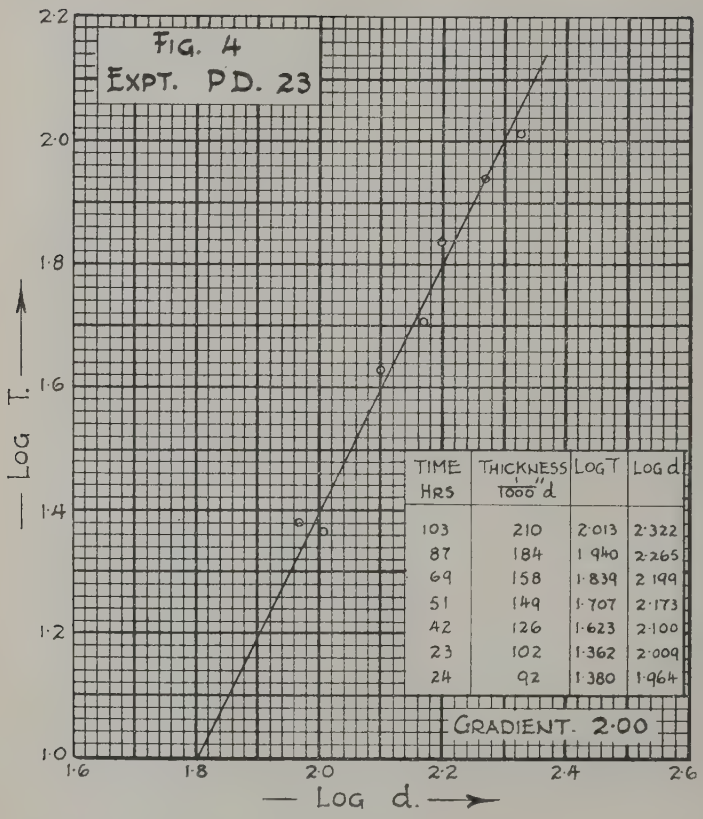

P.D.-23
Moisture %
0
1
2
3
4
5
6
7
8
9
10
TIME HOURS
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120

FIGURE 3

FIGURE 4



DIFFUSION-CONTROLLED PERIOD

(i) *General Analysis*

To confirm the view that the drying from 10 per cent moisture was controlled by diffusion, the logarithm of the time taken to dry from 10 per cent to 0.1 per cent moisture-content was plotted against the logarithm of the thickness, as shewn in Fig. 4. In each case the curve approximated closely to a straight line of gradient 2. The gradients for all experiments were determined and appear in Table I, together with an analysis of the probable error.

TABLE I

Experiment No.	Gradient	Difference from mean	Difference^2
13	1.49	.58	.336
14	2.06	.01	—
15	2.33	.26	.067
18A	2.04	.03	.001
18B	2.18	.11	.012
20	2.12	.05	.003
22	1.91	.16	.026
23	2.00	.00	—
24	2.09	.02	—
25A	2.33	.26	.067
25B	2.04	.03	.001
26A	2.08	.01	—
26B	2.28	.21	.044
27A	2.13	.06	.004
27B	1.87	.20	.040
28A	1.85	.22	.048
28B	1.82	.25	.063
29A	1.89	.18	.032
29B	2.22	.15	.023
31A	2.00	.07	.005
31B	1.76	.31	.096
32A	2.50	.43	.184
32B	2.30	.23	.053
TOTAL	47.29		1.105
MEAN	2.056		

$$\text{Standard Deviation} = \sqrt{\frac{1.105}{22}} = 0.224$$

$$\text{Probable Error} = \frac{0.224}{\sqrt{23}} = \underline{0.047}$$

Since a straight line of gradient 2 is obtained by plotting logarithms of the general parabolic equation $y = kx^2$, it is seen that the results agree closely with the theoretical deduction, that when diffusion is the controlling factor the time required to dry a material through any given moisture-range is proportional to the square of the thickness. This agreement confirms the conclusion that diffusion is the controlling factor in the drying of rubber below 10 per cent moisture-content.

The differential equation for diffusion quoted earlier may be expanded into the following series for the slab, according to Newman *(loc. cit)*.

$$\frac{w-C_1}{C_0-C_1}=\frac{8}{\pi^2}\left[e^{-\left\{\frac{k\theta}{a^2}\right\}\left\{\frac{\pi}{2}\right\}^2}+\frac{1}{9}e^{-9\left\{\frac{k\theta}{a^2}\right\}\left\{\frac{\pi}{2}\right\}^2}+\frac{1}{25}e^{-25\left\{\frac{k\theta}{a^2}\right\}\left\{\frac{\pi}{2}\right\}^2}+\ldots\ldots\right]$$

where the following notation is used:—

- k is the diffusivity constant expressed as pounds per hour flowing across one square foot when the concentration-gradient is one pound per cubic foot per foot length in the direction of flow. It has absolute dimensions of square feet per hour.
- θ is the time in hours
- a is half the thickness of the slab in feet
- w is the final average liquid concentration in lb. per cubic foot
- C_1 is the equilibrium liquid concentration in the same units
- C_0 is the initial uniform liquid concentration in the same units.

The term $\frac{w-C_1}{C_0-C_1}$ is therefore a numerical ratio and is independent of the units used, provided they are consistent for the three terms. In the present case the moisture-contents are expressed as percentages on the dry weight of rubber. This ratio may be denoted by "E." A table of values for the term $\frac{k\theta}{a^2}$ for various values of E has also been published by Newman *(loc. cit.)*

Sherwood[4] has pointed out that the above analysis is based on the assumption of a uniform distribution of moisture across the thickness of the slab or sheet, at the beginning of the diffusion period. Unless drying is started exactly at the critical point the assumption of uniform moisture distribution cannot be valid. It is further suggested by Sherwood that if the constant rate drying period is sufficiently long, a parabolic moisture-distribution is set up across the sheet, and he derives equations for this case. The same author also draws attention to a limiting case, which occurs when the initial drying is very rapid, and there is not time in the short constant rate period for a parabolic moisture-distribution to be reached before the surface concentration of moisture is reduced

to zero, and the following series is given as the equation for this case:—

$$E^1 = \frac{96}{\pi^4}\left[c^{\left\{\frac{k\theta}{a^2}\right\}\left\{\frac{\pi}{2}\right\}^2} + \frac{1}{81} c^{-9\left\{\frac{k\theta}{a^2}\right\}\left\{\frac{\pi}{2}\right\}^2} + \frac{1}{625} c^{-25\left\{\frac{k\theta}{a^2}\right\}\left\{\frac{\pi}{2}\right\}^2} + \cdots \right]$$

E^1 in this equation corresponds to the value denoted previously by E. It is the ratio of the free-water-content at time θ to the free-water-content at the critical point.

Sherwood *(loc. cit.)* has calculated values of E^1 for various values of $\frac{k\theta}{a^2}$ and these results are reproduced in table II A.

Further values obtained by the writer are given in table II B.

TABLE II A

$\frac{k\theta}{a^2}$	E^1
0	1.0
.02	.951
.05	.880
.10	.775
.15	.684
.20	.605
.30	.473
.50	.290
1.0	.086

TABLE II B

$\frac{k\theta}{a^2}$	E^1
.60	.224
.65	.198
.70	.175
.75	.154
.80	.137
.90	.106
.95	.094
1.05	.0738
1.10	.0640
1.15	.0576
1.20	.0505
1.30	.0396
1.40	.0310
1.50	.0143

Sherwood[5] has also suggested the use of a special graph paper with a uniform abscissa scale, but having the ordinate scale adjusted to force the above theoretical equation into a straight line. This technique is extremely helpful since experimental values for E^1 can be plotted directly against θ or against θ/a^2 and in both cases the results should fall on straight lines. Rapid comparison is thus possible between the theoretical derivation and the observed values, and the value of the diffusivity constant (k) is easily determined.

As previously stated, this analysis depends on the assumption that drying proceeds very rapidly in the period controlled by evaporation, and that the surface is dry by the time that the critical point is reached. Rubber approximates closely to these conditions. The high rate of drying of sheet in the early stages is shewn in Fig. 2, and it is common knowledge that the surface of wet rubber is dry to the touch after a very short period of drying. The results were therefore set out using this method and compared with Sherwood's theoretical equation.

Curves shewing the total moisture content at various times during the drying had already been plotted as shewn in Figs. 2 and 3. For the earlier experiments each curve represented the mean results from two sheets of rubber, both machined at the same settings, from the same latex. Whereas in the later ones the results for each sheet were plotted separately, and each batch of sheets was divided into two series of identical sheets, (A) and (B), which were submitted to slightly different soaking and dripping treatments before being dried together. From each curve the time taken for the moisture content to fall from 10 per cent to certain arbitrary levels was taken and a table prepared of this time divided by the thickness squared. An example is given in Table III. This provided the necessary data for plotting E^1 against θ/a^2 according to the method outlined above. This example was typical of the whole series of experiments. The values of θ/a^2 for each value of E^1 in each experiment were reasonably constant and were averaged as shewn in the table. Values of this variable for thin sheets and for all sheets at high values of E^1, were those most liable to error since the time intervals were short.

Table IV shews the mean values of θ/a^2 determined as in the above example, for the whole series of experiments involving the drying of approximately 250 sheets. The average temperature in the drying cabinet is also given for each test. The results are arranged in ascending order of temperatures.

TABLE III

Experiment PD 23

Curve No.		1		2		3		4		5		6		7		
Thickness $\frac{\text{ins.}}{1000}$		210		185		158		149		126		102		92		
$\left\{\frac{\text{Thickness}}{2}\right\}^2$ ft. $\times 10^5$ $= a^2$		7.60		5.85		4.32		3.84		2.74		1.80		1.46		Mean
Moisture Per cent.	E^1	Time θ	θ/a^2	Time θ	θ/a^2	Time θ	θ/a^2	Time θ	θ/a^2	Time θ	θ/a^2	Time θ	θ/a^2	Time θ	θ/a^2	$\frac{\theta}{a^2} \times 10^5$
8	0.8	3	0.395	3	0.513	2	0.463	1	0.360	0.5	0.183	1	0.556	1	0.684	0.451
6	0.6	10	1.316	8	1.367	7	1.622	4	1.042	2	0.730	2	1.111	2	1.369	1.222
5	0.5	16	2.105	13	2.241	11	2.549	8	2.084	5	1.826	3	1.667	2.5	1.711	2.026
4	0.4	26	3.421	21	3.588	16	3.702	13	3.385	7	2.555	4	2.222	3.5	2.395	3.038
3	0.3	36	4.737	29	4.959	22	5.090	19	4.949	11	4.015	6	3.334	5	3.424	4.358
2	0.2	49	6.443	40	6.830	30	6.942	27	7.035	16	5.842	9	5.000	8	5.479	6.224
1	0.1	65	8.555	55	9.404	38	8.802	36	9.382	23	8.395	14	7.770	13	8.895	8.743
0.5	0.05	78	10.260	65	11.105	46	10.650	42	10.940	29	10.580	18	10.000	17	11.640	10.739
0.3	0.03	87	11.445	72	12.305	52	12.040	47	12.240	34	12.410	20	11.110	20	13.690	12.177

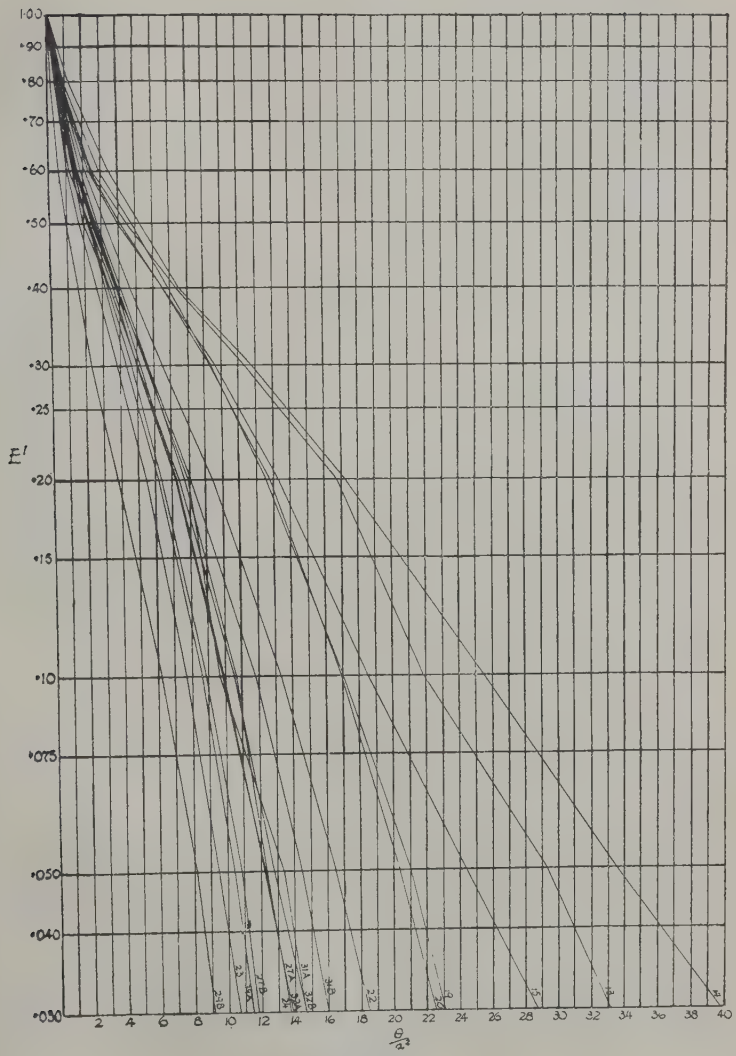
TABLE IV

$$\frac{\theta}{a^2} \times 10^{-5}$$

Expt. No.	Temp. °F	Values for E'								
		.8	.6	.5	.4	.3	.2	.1	.05	.03
13	117.0	0.78	2.46	4.47	7.38	11.41	16.73	21.85	29.21	33.08
14	117.7	1.22	3.35	—	7.44	11.88	17.16	25.47	33.52	39.75
15	121.6	0.62	2.38	4.07	6.48	9.65	13.23	18.50	24.36	28.72
18 A	122.8	0.31	1.22	2.72	4.47	6.88	9.70	13.66	18.54	20.97
18 B	122.8	0.94	2.60	3.99	6.06	8.50	11.50	15.63	18.44	19.68
20	129.0	0.66	2.30	3.98	6.46	9.30	12.73	16.96	20.34	22.53
31 A	129.5	0.54	1.65	2.55	3.82	5.50	7.84	9.59	13.31	14.65
31 B	129.5	0.38	1.47	2.42	3.81	5.63	8.08	11.83	14.46	15 99
19	130.5	0.84	2.89	4.67	6.80	9.32	12.47	17.02	20.99	23.05
32 A	131.5	0.44	1.17	2.23	3.62	5.00	7.22	9.86	12.31	13.89
32 B	131.5	0.41	1.29	1.95	3.41	4.98	7.26	10.45	12.85	14.71
22	132.3	0.63	2.05	3.17	4.62	6.46	9.33	13.34	16.49	18.37
24	132.3	0.58	1.85	2.75	4.03	5.61	7.61	10.59	12.33	13.71
23	134.8	0.45	1.22	2.03	3.04	4.36	6.22	8.74	10.74	12.18
26 A	138.4	0.60	1.74	2.58	3.75	5.09	6.94	9.36	11.76	13.28
26 B	138.4	0.43	1.15	1.99	3.12	4.46	6.59	9.40	11.78	13.00
25 A	138.8	0.44	1.32	2.01	3.07	4.30	5.90	8.69	10.99	12.39
25 B	138.8	0.25	0.86	1.69	2.44	3.91	5.78	8.30	10.17	11.36
27 A	140.0	0.60	1.62	2.56	3.76	5.20	7.19	9.90	12.21	13.89
27 B	140.0	0.50	1.44	2.17	3.27	4.66	6.37	8.82	10.86	11.79
28 A	144.6	0.20	0.70	1.06	1.87	2.99	4.45	6.57	8.16	9.05
28 B	144.6	0.23	0.65	1.08	1.75	2.62	4.00	5.94	7.51	8.37
29 A	150.6	0.45	1.45	2.12	3.11	4.22	6.10	8.58	10.42	11.54
29 B	150.6	0.20	0.48	0.92	1.56	2.29	3.76	6.17	8.14	9.13

These values were then plotted on the specially constructed graph paper, suggested by Sherwood, on which the theoretical relationship between E' and $k\theta/a^2$ gives a straight line. Any deviations must be due either to variations in the diffusion factor (k) during the drying, or to errors in the experimental determination of the term θ/a^2. Of the two measurements involved here, namely the time, and the thickness, the former is more liable to error since it was obtained by interpolation from the original curves.

FIGURE 5


1·00
·90
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·70
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·040
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4
6
8
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12
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20
22
24
26
28
30
32
34
36
38
40
θ/a²

FIGURE 6

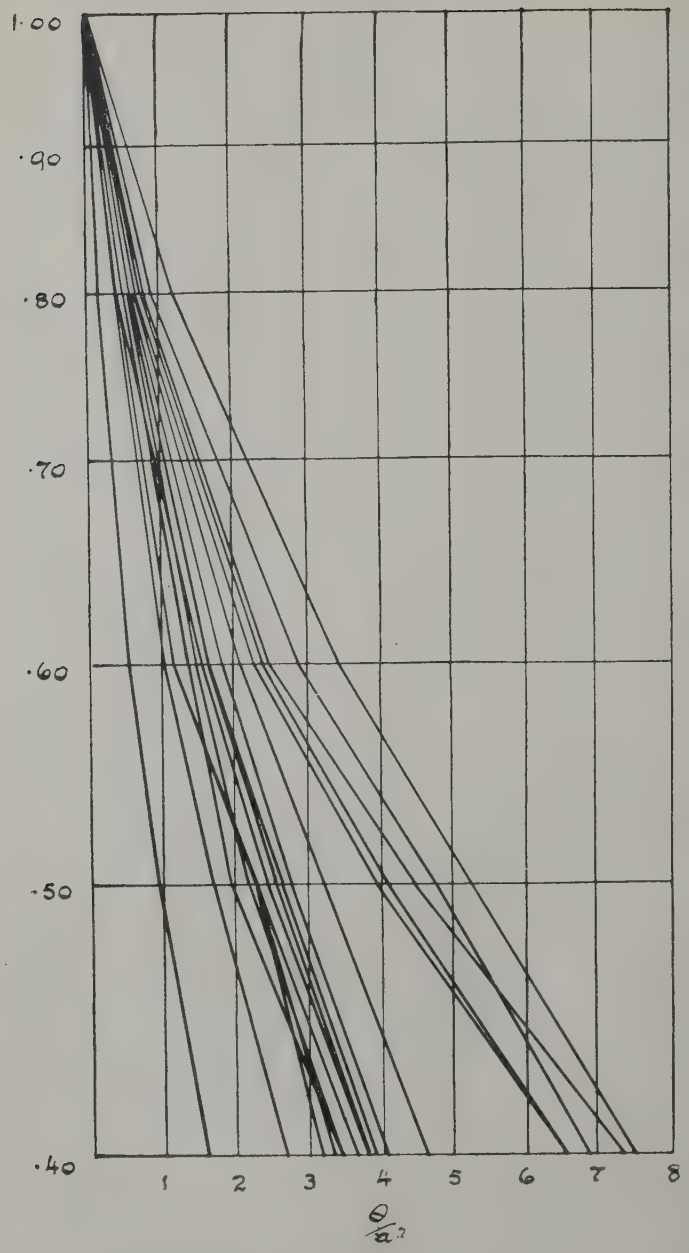


Fig. 5 shews a number of the results from Table IV, plotted by this method. Fig. 6 is an enlargement of the upper portion of the same curves. It will be observed that, considered over the whole range of values of E^1, from 1.0 to 0.03 the lines are reasonably straight, hence the assumption that the surface of the rubber sheet is already dry at the critical moisture content of 10 per cent is not very far from the truth. Fig. 6 however shews that the top portion of the lines are concave upwards. This deviation from the straight line is small, but consistent, and is therefore likely to be due to variations in the value of the diffusion constant (k) rather than to experimental errors. As the drying progresses the curves tend to be slightly convex upwards. These deviations indicate that the diffusion rate at first falls off and then, when the rubber is nearly dry the rate rises slightly again. It is probable that the first decrease is due to the shrinkage of rubber during drying. The same phenomenon has been observed in the case of clay[4]. The later rise is not well marked and may be illusory. One possible explanation, however, is that although the air temperature remained constant throughout, when the rubber was approaching dryness the heat lost through the evaporation of the diffused moisture would decrease, and the small amount of radiation from the shielded heating elements may then have been sufficient to raise the sheet temperature a little above that of the surrounding air.

The value for the diffusivity factor (k) is determined by dividing the value of $k\theta/a^2$ from Table II A or II B for any given value of E^1, by the figure for θ/a^2 for the same value of E^1 from Table IV. This was done for values of E^1 corresponding to 6 per cent, 3 per cent and 1 per cent moisture content, and the results are shewn in Table V.

(ii) *Effect of External Condition on Diffusion Constant*

It will be observed from Tables IV and V that the value of the diffusion constant (k) increases fairly regularly and rapidly with rise of temperature, for any particular value of E^1. The deviations from this regularity are at least partially explicable by the variation in

(a) ventilation conditions
and (b) draining periods at air temperature from experiment to experiment.

(a) *Ventilation conditions*

It is seen that the values of the diffusion constant (k) increased gradually with increase of temperature but over that portion of the range where natural ventilation was used, the values of (k) were

TABLE V

Values of k

Expt. No.	Mean Temp. F.	Soaking Period after Machining Hrs.	Natural or Forced Draught.	Time of Dripping in Air Hrs.	$E^1=.6$ $k\theta/a^2=.215$ $\frac{\theta}{a^2}\times 10^{-5}$	$K\times 10^{5}$	$E^1=.3$ $k\theta/a^2=.485$ $\frac{\theta}{a^2}\times 10^{-5}$	$K\times 10^{5}$	$E^1=.1$ $k\theta/a^2=.922$ $\frac{\theta}{a^2}\times 10^{-5}$	$K\times 10^{5}$	Mean Relative Humidity.
13	117.0	2	Forced	2	2.46	.0874	11.41	.0425	21.85	.0422	—
14	117.7	2	„	2	3.35	.0642	11.88	.0409	25.47	.0362	—
15	121.6	2	„	2	2.38	.0904	9.65	.0503	18.50	.0499	—
18A	122.8	2	„	2	1.22	.1762	6.88	.0706	13.66	.0675	27.1
18B	122.8	2	„	2	2.60	.0826	8.50	.0571	15.63	.0590	27.1
20	129.0	1	„	0	2.30	.0936	9.30	.0522	16.96	.0544	28.1
31A	129.5	1	Natural	0	1.65	.1303	5.50	.0882	9.59	.0962	24.7
31B	129.5	1	„	3	1.47	.1462	5.63	.0862	11.83	.0780	24.7
19	130.5		Special Treatment See Table 6		2.89	.0744	9.32	.0521	17.02	.0542	—
32A	131.5	1	Natural	0	1.17	.1838	5.00	.0971	9.86	.0935	24.2
32B	131.5	1	„	3	1.29	.1667	4.98	.0974	10.54	.0875	24.2
22	132.3	1	„	0	2.05	.1049	6.46	.0751	13.34	.0692	27.6
24	132.3	1	„	0	1.85	.1161	5.61	.0865	10.59	.0871	26.7
23	134.8	1	„	0	1.22	.1762	4.36	.1112	8.74	.1057	24.1
26A	138.4	1	Forced	0	1.74	.1236	5.09	.0953	9.36	.0986	19.8
26B	138.4	1	„	3	1.15	.1870	4.46	.1086	9.40	.0982	19.8
25A	138.8	1	„	0	1.32	.1628	4.30	.1128	8.69	.1061	22.7
25B	138.8	1	„	3	.86	.2501	3.91	.1240	8.30	.1111	22.7
27A	140.0	1	„	0	1.62	.1327	5.20	.0943	9.90	.0932	21.0
27B	140.0	1	„	3	1.44	.1492	4.66	.1040	8.82	.1045	21.0
28A	144.6	1	„	0	.70	.3072	2.99	.1622	6.57	.1402	18.7
28B	144.6	1	„	3	.65	.3308	2.62	.1851	5.94	.1552	18.7
29A	150.6	1	„	0	1.45	.1482	4.22	.1149	8.58	.1074	17.5
29B	150.6	1	„	3	.48	.4482	2.29	.2119	6.17	.1495	17.5

consistently slightly higher than would have been expected from those obtained in the experiments using forced draught. This cannot be due to any humidity difference, since the forced draught system merely withdrew air from the top of the cabinet and returned it to the bottom, at such a rate that the air was completely circulated once every three minutes, with approximately 7 per cent rejected at each circulation. For the tests in which the blower was not employed, ventilators were arranged to change the air once every 40 minutes. The same amount of air was thus admitted to the cabinet in either case. Throughout the experiments it was found that after the first two or three hours, the moisture content of the air in the drying chamber was almost exactly that of the surrounding atmosphere. The relatively higher values of the diffusion factor (k) obtained when using natural ventilation may have been due to one or both of two factors. First, although the heaters were shielded by asbestos board, a certain amount of radiation on to the sheet may have occurred. This would tend to raise the sheet temperature above that of the air from which the temperature records were derived. A higher air velocity in these circumstances would minimise possible differences between the temperature of the sheet and that of the air. Evidence in support of this theory is provided by the finding that when forced draught was used, higher drying temperatures could be employed with less risk of damage to the sheet by blistering. The second possibility is that a dry impervious skin may have been formed on the surface of the sheet rubber during drying. A high air velocity would tend to increase this effect.

(b) *Draining periods at air temperature*

Another variable in the drying conditions was the period for which the sheet was hung in the air before being transferred to the heated cupboard. For purposes of calculation this period was regarded as part of the drying time. The results quoted in Table V shew that for high values of E^1 the value of (k) was usually higher for those sheets placed in the hot chamber immediately after soaking. As drying proceeded, and E^1 diminished, this difference practically disappeared. Further evidence for the effect of the draining period on the value of (k) was derived from the results of experiment 19 which appear in Table VI.

Here two of the sheets were left out in the air for the first 22 hours of the drying time and the moisture content was reduced to just over 5 per cent., whereas similar sheets which had been drained for shorter periods before being placed in the drying cupboard reached 3 per cent moisture in the same time. Yet the total time taken to dry these two sheets was if anything slightly less than

TABLE VI

Experiment No. 19

Sheet	No. 1		No. 2		No. 3		No. 4		No. 5		No. 6		No. 7		No. 8	
Thickness	0.123 in.		0.121 in.		0.124 in.		0.127 in.		0.129 in.		0.134 in.		0.122 in.		0.125 in.	
Soaked	0.5 Hr.		0.5 Hr.		0.5 Hr.		0.5 Hr.		2 Hrs.		2 Hrs.		2 Hrs.		2 Hrs.	
Dripped	3 Hrs.		3 Hrs.		1.5 Hr.		1.5 Hr.		1 Hr.		1 Hr.		22 Hrs.		22 Hrs.	
Time	Moisture Per cent	Time	Moisture Per cent	Time	Moisture Per cent	Time	Moisture Per cent	Time	Moisture Per cent	Time	Moisture Per cent	Time	Moisture Per cent	Time	Moisture Per cent
0	33.13	0	33.74	0	31.81	0	30.51	0	27.89	0	25.89	0	27.98	0	28.20
3	11.90	3	11.25	1.5	22.24	1.5	22.03	1	20.56	1	18.39	3	12.95	3	15.37
5	7.43	5	7.20	5	7.51	5	7.59	3.5	8.57	3.5	7.63	22	5.35	22	5.18
23	3.12	23	2.85	23	3.38	23	2.98	21	3.58	21	3.89	24.5	4.31	24.5	4.02
26	2.82	26	2.70	26	2.80	26	2.53	24.5	3.12	24.5	3.44	27.5	3.57	27.5	3.28
29	2.52	29	2.25	29	2.35	29	2.23	27.5	2.65	27.5	3.28	45	0.74	45	0.89
47	1.18	47	0.60	47	0.74	47	0.60	45	0.78	45	1.20	51	0.74	51	0 45
53	0.74	53	0.60	53	0.74	53	0.60	51	0.78	51	0.75	69	0.15	69	0
71	0.15	71	0	71	0	71	0.30	69	0.16	69	0	73	0	73	0
74	0	—	—	74	0	74	0.15	73	0.16	73	0	—	—	—	—
—	—	—	—	—	—	98	0.15	97	0	—	—	—	—	—	—
—	—	—	—	—	—	119	0	—	—	—	—	—	—	—	—

that required by those sheets which had spent almost the whole period at a higher temperature. Thus the value of the diffusion constant (k) for sheets dried for the first 22 hours in air must have been higher than that for those drained for shorter periods. Although it is dangerous to draw conclusions from such limited evidence, this is an indication that the speed of the early part of the drying affects (k) thus supporting the view that a dry surface film, which hinders further drying, may be formed on the rubber. This is a well-known phenomenon with other materials and is usually termed surface checking. Although Table V indicates that ventilation and draining conditions do have an effect on the value of the diffusion constant (k) it also indicates that the effect of these variables is not sufficiently great for them to be of major importance in practice.

(c) *Effect of Compression during Rolling*

There is one further point on which the results offer certain evidence. It may be expected that the increased rolling necessary to produce a thinner sheet would reduce the porosity of the rubber sufficiently to produce an adverse effect on the diffusivity factor (k). This would produce a deviation from the theoretical relationship that drying time is directly proportional to the square of the thickness. A study of the values of θ/a^2 for the whole range of experiments, indicated that this ratio did tend to increase slightly as the sheet thickness diminished. The detailed example which forms Table III is typical. The effect was small, however, and was far outweighed by the reduction in time secured by producing thin sheet.

(d) *Effect of Surface Area of Sheet*

It will be observed that none of the foregoing deductions take into consideration the area of the sheet. This omission is justifiable since the thickness of the sheet was so small in comparison with its other dimensions that no error was involved in neglecting the edge effects and regarding the behaviour as similar to that of a sheet of infinite area.

(e) *Effect of Relative Humidity of Air*

The effect of the relative humidity of the air has also not been taken into account in calculating the results. As was pointed out earlier, this cannot affect the rate of drying so long as it is sufficiently low to permit moisture to evaporate faster than it can diffuse to the surface. Since the rate of diffusion has been shewn

to control the rate of drying over the major portion of the total time required, the relative humidity of the air did not affect the calculations.

(iii) *Summary*

Summarising at this stage, it may be said that the greater portion of the time taken to dry normal sheet rubber is occupied in drying beyond a 10 per cent moisture content, and that the rate at which this drying occurs is controlled by the rate of diffusion. The two principal means by which drying time can be reduced are by increasing the temperature and reducing the thickness of the sheet. There are indications that surface checking occurs but the experiments so far carried out give no clue as to its severity. The available evidence indicates either that effect is so small as to be unimportant in practice, or the phenomenon is so pronounced that simple practical measures, such as drying slowly at atmospheric temperatures for the first few hours, which should alleviate the trouble, have little effect. It is hoped that further experimental work will be possible to decide the extent of this surface checking. It is feared, however, that even if it is found to be important, the only method likely to expedite the drying will be humidity control irrespective of temperature, which would probably prove impracticable for an estate factory. In this connection it should be borne in mind that the relative humidity of the atmosphere is very high in rubber-growing countries, and that the sheet is normally dripped for a few hours at atmospheric temperature before it is transferred to the smoke-house, where the temperature is raised gradually. Thus sheet rubber is in practice dried slowly and at high humidity in the early stages. Further improvements on these lines are therefore unlikely.

Constant Rate Period

Attention up to this stage has been directed mainly to the diffusion-controlled portion of the drying. As was pointed out in reference to Fig. 2, the evaporation-controlled period during which the rubber dried down to 10 per cent moisture-content occupied a small proportion of the total time. Actually the thickest sheets in the experiment plotted in Fig. 2 were 0.21 inch thick and contained initially 67 per cent of free moisture. Their total drying time was 115 hours, but the moisture content had fallen below 10 per cent in less than eight hours. The thinnest sheets in the same series were 0.092 inch thick and had an initial moisture content of about 21 per cent and a drying time of 25 hours. Here the moisture-content reached 10 per cent in less than 1½ hours.

Further confirmation may be obtained from Table VI. The conditions controlling the constant-rate phase of the drying were stated in the preliminary discussion, and have been well established by the work of Hinchley and Himus,[6] and others. Since they are independent of the nature of the material being dried, except in so far as it may be hygroscopic, and since the technique used in this work did not permit of the measurement of drying over short intervals of time, it is not proposed to offer any experimental results for this evaporation-controlled period. It may be mentioned, however, that all the graphs of moisture-content against time were nearly straight over this region, as they should be according to the theory.

Zone of Unsaturated Surface Drying

Mention of the initial portion of the falling rate period, which is referred to in the preliminary discussion as the "zone of unsaturated surface drying" has also been omitted from the experimental analyses. It occurs between the first and second critical moisture contents. At first sight there appears to be no reason for the existence of this period under the conditions of this experiment, since a uniform smooth surface was exposed and there was thus no cause to expect one portion of the surface to be dry before the remainder. In contradiction to this it must be pointed out that the rubber was hung over bars and drainage of the surface film of water towards the lower edges would therefore occur, causing the film to be thicker at these points.

When it is remembered that in this zone the rate of drying is still controlled by the rate of evaporation, which has already been shewn to be very much larger than the rate of diffusion, it will be apparent that the effect of this period on the total drying time must be small. Further, there is no extraneous factor apart from those already considered in relation to the constant-rate period which can affect the drying rate in this zone, and there is thus little to be gained from a study of it. Owing to the intermittent weighing method adopted during these tests, it was found impossible in practice to locate the first critical point, and the zone of unsaturated surface drying; since the slight difference in rate which it could be expected to cause, from that of the constant rate period, was within the limits of experimental error. It was therefore regarded as part of the constant-rate evaporation-controlled period.

Comparison of Results with those Previously Published [8]

Although the evaporation-controlled period was short it was not negligible, and should be sufficient to produce an appreciable

deviation from the relationship stated by Van Harpen *(loc. cit.)*, namely, that the total drying time is proportional to the square of the thickness. To check this, the logarithm of the time required to dry from the initial moisture content to 0.1 per cent moisture content was plotted against the logarithm of the thickness in a manner similar to that used for Fig. 4. Once again the lines were straight and the gradient was almost exactly 2. The actual results are given in Table VII, which is comparable with Table I, except that in this case those experiments which were previously divided into A and B portions are here treated as one.

TABLE VII

Total Time versus Thickness Squared

Expt. No.	Gradient	Difference from mean	Difference^2
13	1.57	0.41	0.168
14	1.90	0.08	0.006
15	2.13	0.15	0.025
18	2.25	0.27	0.073
20	2.08	0.10	0.010
22	1.75	0.23	0.053
23	1.96	0.02	0.000
24	1.89	0.09	0.008
25	1.92	0.06	0.004
26	2.18	0.20	0.040
27	2.08	0.10	0.010
28	2.02	0.04	0.002
29	1.89	0.09	0.008
31	1.68	0.30	0.090
32	2.38	0.40	0.160
TOTAL	29.68		0.657
MEAN	1.98		

$$\text{Standard Deviation} = \sqrt{\frac{0.657}{14}} = \sqrt{0.0470} = 0.217$$

$$\text{Probable Error} = \sqrt{\frac{0.0470}{15}} = 0.056$$

It has thus been shewn that the total drying time, and the time to dry from 10 per cent moisture content are both proportional to the square of the thickness. Also it was stated that the rate of drying from the initial moisture content down to 10 per cent moisture was constant and independent of the thickness. These facts can be reconciled only if the initial moisture content minus 10 per cent is proportional to the square of the thickness.

The experimental results were examined to test this conclusion. It was found to be approximately correct as is shewn in Table VIII.

TABLE VIII

Experiment PD 23

Initial Moisture Minus 10 per cent. = M	Thickness Inches = d	$\frac{M}{d^2} \times 10^{-3}$	Number of Machinings
56.98	0.211	1.28	3
48.07	0.185	1.41	3
31.72	0.158	1.27	4
24.41	0.150	1.09	4
20.69	0.126	1.30	5
12.60	0.102	1.21	5
10.94	0.092	1.29	5
		Mean 1.26	

The results from a number of other experiments selected at random were closely similar. It was found, however, that for thin sheets which had been passed many times through the machine there was a deviation from the mean. Experiment 13 of which details are given in Table IX was the one in which the highest number of passes through the machines was used, and affords the best illustration of this finding.

It will be seen that the ratio between the initial moisture content minus 10 per cent, and the square of the thickness is only approximately constant but a high order of accuracy is not necessary to explain the evident relationship between Van Harpen's

findings, and the deductions in this paper, since, in any case, the time taken for the initial, evaporation-controlled portion of the drying is small, in comparison with the total time required.

TABLE IX.

Experiment 13

Initial Moisture Minus 10 per cent. = M	Thickness Inches = d	$\frac{M}{d^2 \times 10^{-3}}$	Number of Machinings
74.6	0.250	1.19	2
55.2	0.214	1.20	3
47.5	0.195	1.25	4
39.7	0.196	1.04	5
13.2	0.195	1.14	6
44.1	0.175	1.45	7
23.8	0.150	1.07	8
16.1	0.133	0.91	9
8.0	0.116	0.59	10
6.1	0.109	0.52	11

Conclusions

The relationship stated by Van Harpen that the total time required to dry sheet rubber is proportional to the square of the thickness has been shewn to be an accurate working rule, although it did not at first sight appear to accord with general drying theory. By far the greater proportion of the time in drying rubber is controlled by diffusion, and approximate values of the diffusivity constant are given. A high order of accuracy is not claimed, since the critical moisture-content was difficult to determine, and although 10 per cent appeared a good average value it may have varied slightly for different experiments and even for different samples in the same test run. The two main methods by which drying time can be reduced are:—

(i) the production of thinner sheet

(ii) the use of higher temperatures.

There is an initial period of the drying during which the rate is controlled by the rate of evaporation. Here the time may be reduced by increasing the air velocity. There is little advantage to be gained in this way, firstly since the initial period represents a small proportion of the total time, and secondly because there is some evidence that surface checking occurs. This effect is increased by rapid drying in the early stages and it has an adverse effect upon the diffusion rate. The effect of various marking patterns on the drying time is another important aspect which remains to be investigated.

Practical Applications

The production of thin sheet and the use of high temperatures have been stressed as the two main methods available for reducing the time required to dry sheet rubber. There are obvious limitations to the extent to which either can be applied in practice.

(i) *Sheet Thickness*

Attempts to produce extremely thin sheet lead to a number of difficulties, some of which are listed below.

(a) The width of the dry sheet should be limited to 19 inches for easy packing, and if very thin sheet is to be produced without exceeding this width, the depth of latex used in the coagulating tanks may need to be restricted.

(b) The production of very thin sheet imposes added work on the sheeting battery. The output per hour is decreased, partly due to the increase in area required per pound of rubber and partly to the increased slip which occurs between the rubber and the rolls. All play must be eliminated from the rolls and bearings. Unless the number of pairs of rolls is increased in proportion to the reduction of thickness required, a greater squeezing effect must be obtained from each pair, and under these conditions difficulty may be experienced in making the rubber enter the nip. It may even be found that the thickness required is beyond the powers of the battery, in which case it becomes necessary to reduce the dry rubber content at which the latex is coagulated. This in turn necessitates the provision of a larger number of coagulating tanks for the same crop.

(c) Very thin sheets are limp and difficult to handle. They tear easily and are liable to stick together when piled or when hanging in the smoke-house. They also require increased smoke house space per unit weight of rubber.

Modern sheeting batteries have proved capable of producing satisfactory sheet 0.10 inch thick from coagulum prepared from

latex containing 1.5 pounds of rubber per gallon, in standard tanks. This represents the practical limit, beyond which the above difficulties become important. It should be emphasised that a batch of rubber is not dry until the thickest portion of the thickest sheet is dry. Uniformity of thickness is therefore of vital importance, and in practice there is frequently more scope for reduction of the total drying time by attempts to eliminate thick patches and odd thick sheets in the batch, than there is in attempting to reduce the average thickness of the whole crop.

(ii) *Temperature*

The maximum temperature which can be used is limited by the danger of forming blisters on the sheet. It has been found that the safe maximum increases as drying proceeds, and it is therefore desirable to increase the temperature gradually during drying. In a separate paper elsewhere in this *Journal* will be found a description of two forms of a successful modern smoke house, together with notes which have been compiled from experience on the operation of this type. It will be observed that a four days drying period is recommended and that the temperature is increased gradually from 100° F to 140° F. Higher temperatures have been used but these leave a very small margin of safety.

(iii) *Drying Time*

Although four days is the recommended period, there is little difficulty in drying sheet 0.10 inch thick in three days in the "Subur" smoke-house if desired, and there are special patented dryers capable of drying thin sheet rubber in 48 hours. In the smoke-house, however, two processes are in operation, for while being dried, the rubber absorbs certain ingredients from the wood smoke, and becomes coloured. Some users prefer a well-smoked sheet to one which is very pale in colour. The smoke not only acts as a disinfectant which renders the rubber somewhat less liable to mould attack, but it also appears to improve the ageing properties of the rubber after vulcanisation[7]. If rubber is dried too rapidly, difficulty may be experienced in producing sheet sufficiently dark in colour to meet with the approval of certain manufacturers. It has been found in practice, however, that rubber absorbs very little smoke when it is nearly dry. This is the reason for the recommendation of a four days' drying period, with comparatively low temperatures for the first 48 hours. It is also a further argument against attempts to carry the reduction of thickness to extremes.

It therefore appears unlikely that there will be any radical change in the method of drying rubber so long as smoked sheet, of the type now produced almost universally, remains the main form in which rubber is exported. It is considered that there is still room for minor improvements in the design and thermal efficiency of smoke-houses, and possibly for some small reduction in the time required to dry and smoke the rubber, but it is feared that the automatic machine which can convert the wet rolled coagulum into dry smoked sheet in a few hours, will remain unrealised.

Acknowledgements

The author is indebted to Dr. E. Rhodes for his encouragement during the experiments and his assistance in preparing the paper for publication.

Literature cited

(1) Newman A. B. *Trans. Am. Inst. Chem. Eng.* **27** (1931) 313
(2) Perry *Chem. Engineers' Handbook* (1934) 1224
(3) Van Harpen *Archief voor de Rubbercultuur* **14** (1930) 442
(4) Sherwood T. K. *Trans. Am. Inst. Chem. Eng.* **27** (1931) 190
(5) Sherwood T. K. *Ind. Eng. Chem.* **21** (1929) 12
(6) Hinchley & Himus *Trans. Inst. Chem. Eng.* **2** (1924) 57
(7) Hastings J. D. *J.R.R.I.M.* **6** (1935) 90

Kuala Lumpur,
29th January, 1937

"SUBUR" TYPE SMOKE-HOUSES

(A) ORIGINAL TYPE WITH FURNACES BELOW GROUND LEVEL

(B) MODIFIED TYPE WITH FURNACES ABOVE GROUND LEVEL

BY

A. Moore and J. H. Piddlesden

Introduction

The "Subur" Type Smoke-house is so called because one of the earliest to work satisfactorily was built on Subur Estate, near Taiping. This had its furnaces and flues below ground level. The general design, with a few alterations suggested by experience, was copied on other estates, and during the last two years many smoke-houses of this type have been built.

An important modification of the original type was devised when the manager of a flat, low-lying estate wished to build a "Subur" type smoke-house, but could not have furnaces and flues below ground level because of the high water table in the soil. The contractors, in consultation with the Rubber Research Institute, were finally able to design and build a smoke-house with furnaces and flues on ground level. Details of this are given below. It has been working well for nearly two years on Bernam—Perak Estate, near Telok Anson, and is sometimes referred to as the "Bernam—Perak Smoke House" or the "Overground Subur."

Now that conditions have improved in the plantation rubber industry, many companies are considering building new smoke-houses, and it is felt that descriptions and diagrams of the two forms of the "Subur" type smoke-house should be published for general information.

The diagrams which appear herein are intended to illustrate the principles of the smoke-houses and their general dimensions. They do not contain full details of construction and materials, but from them engineers and contractors will supply detailed plans and estimates to suit individual needs. Various points which deserve special attention are dealt with below.

Principal Features

No Carrying

The fundamental principle on which the design of the "Subur" type smoke-house is based is that there should be no carrying of sheet. This means that the smoking chambers must be on ground level so that trolleys can be loaded with sheet in the factory and pushed along rails into the smoke-house chambers. When the sheet is dry the same trolleys convey it to the packing shed. Carrying of sheet is avoided entirely and handling is reduced to the operations of loading, turning once (optional), and unloading.

Continuous Smoking

Another important feature of these smoke-houses, which gives them an advantage over most older types, is that smoking is very nearly continuous. Except for brief periods each day, when trolleys are being transferred from chamber to chamber and sheet is being examined and turned if desired, there is no interruption. It is never necessary to put out the fire and cool down the house.

Other Advantages

Other advantages of the "Subur" type smoke-houses are the almost negligible risk of fire, low fuel consumption, and reasonable initial cost.

(A) THE ORIGINAL TYPE WITH FURNACES AND FLUES BELOW GROUND LEVEL

Notes on Design

"Single Subur"

The unit of construction is a building divided into four chambers, all served by one furnace. The furnace is at one end and below ground level. The main flue runs underground through the whole length of the building, with branch flues serving each chamber. A verandah is provided so that dripping of freshly-machined sheet, and inspection of partly-dried sheet, can be done under shelter.

"Double Subur"

This consists of two "Single Suburs" joined by a central verandah which serves both. The building shown on the accompanying diagrams is of this type.

Drying Time

In properly regulated "Subur" smoke-houses, sheet of ordinary thickness, *i.e.* between one-tenth and one-eighth of an inch thick, dries in slightly less than four full days.

Capacity

Each chamber, of the size shown in the diagrams, holds two trolleys, and each trolley carries about 900 lb. of sheet, so that each chamber holds about 1,800 lb., dry weight. Since the drying time is just under four days, it means that in the "Single Subur" one chamber is emptied daily, giving an output of 1,800 lb. of sheet per day. The output of the standard size "Double Subur" is, of course, twice this *i.e.* 3,600 lb. per day.

Flexibility of Design

An advantage of the design is that where the crop is small now but will increase later, only a "Single Subur" need be built at first and enlarged when necessary to form a "Double Subur" Also, although the dimensions shown on the diagrams are for a building of convenient size, there is no objection to making smaller chambers to suit smaller crops. For larger crops, chambers each holding three trolleys are practicable, if the furnace and flues are suitably enlarged. It is not advisable to have more than four chambers in line served by one furnace, even when the chambers are small, since control of heating and ventilation becomes too complicated.

Division into Separate Chambers

Drying is quickest and full consumption is lowest if, as drying proceeds, the sheet can be subjected to different degrees of temperature and ventilation. For this reason the "Single Subur" is divided into four separate chambers, each large enough for a day's crop. The four chambers may be kept at different temperatures, with different degrees of ventilation, and until sufficient experience has been acquired this sometimes causes difficulty.

It is suggested that in the "Double Subur" the difficulty will be lessened by dividing each side into two chambers only, instead of into four. Rails, doors, turntables, ventilators, etc. will all be the same as when there are four chambers on each side, but the first and third partition walls will be left out. Each side will then consist of two large double-track chambers each holding four trolleys, and one of these large chambers, which is equal to two small ones, will be used for each day's crop. Control of temp-

erature and ventilation will be made easier because there will be only two distinct chambers served by each furnace, instead of four.

In the "Single Subur", too, some Managers have found that one or more of the partitions can be left out; but in such cases the drying time might be lengthened and the fuel consumption increased because each day's crop is no longer kept separate. There is, however, a saving in labour as it is not necessary to move all the trolleys each day. Where it is not essential to dry in four days, and where fuel costs are not important, it might be worth while to leave out some of the partitions.

Notes on Construction

Flues and Smoke Outlets

The flues should be of the size shown in the diagrams, as they are difficult to clean if made smaller. The smoke outlets leading from the flues into the chambers are between the rails. They should be about 18 ins. x 15 ins. Each one should be covered with a spark arrester of wire gauze held in a loose frame and let in just below the level of the concrete floor. This can be lifted out for cleaning. Flat sliding dampers of sheet steel should be placed over the smoke outlets, to control the amount of smoke and heat entering each chamber. If these sliding dampers are connected to rods passing through the smoke-house wall, they can be adjusted from outside without opening the doors. Over the smoke outlets, and raised about three inches above the floor, are sheet steel baffle plates. These should project beyond the sides of the holes and should have their edges turned down one inch to trap any ash carried up by the smoke.

Furnace Door

The furnace door should have adjustable ventilators so that the rate of combustion of the fuel can be controlled. A suitable furnace door is formed by a vertically sliding cast iron plate balanced by a counterpoise.

Ventilation

Each chamber must have its own adjustable ventilators, both top and bottom.

The top ventilators, one for each chamber, should be placed in the ridge of the roof. They should preferably be of the "piston" type, as these can be adjusted more easily and accurately than

those of the hinged flap type. A diameter of 14 ins. is a suitable size.

Bottom ventilators should consist of rectangular holes in walls and doors, fitted with sheet metal covers which should slide sideways. Two such ventilators, about 9 ins. x 6 ins., are needed in the rear wall of each chamber, a few inches above the floor. A similar sized ventilator should be provided near the bottom of each door.

Doors

Doors may be of wood, or of steel lined with asbestos or sheet metal, and to lessen heat losses there should be an air space of about two inches between the door and the lining. For efficient insulation this space must be airtight. To prevent unwanted air from leaking into the chambers, and thus interfering with the control of temperature and ventilation, doors should be made to fit properly. They are less likely to drop if the hinges of adjoining doors are made in one piece and passed right through the supporting pillar, so that the two doors balance each other.

Inspection Window

There should be an inspection window or trap door in the rear wall of each chamber, about five feet above the floor, so that a thermometer hung inside can be read without opening the door.

Roof

The roof may be of corrugated iron or asbestos, with a lining of wood or asbestos board. This lining should be airtight, fitting closely against the top of the walls, and the space between the lining and the roof should also be as nearly airtight as possible.

There must *not* be any flat inner ceiling. This would restrict the circulation of air and result in cold spots and uneven heating, which might in turn cause condensation, moulds, and other troubles.

Walls

Bricks are generally used for building the walls, but hollow concrete blocks have recently been tried and proved successful. For walls of the same thickness they are cheaper than bricks, and give better insulation against heat losses.

Trolleys, Turntables, and Rails

Trolleys should be light but rigid. To prevent tilting, the wheelbase should be at least four feet long. This means correspondingly large turntables. Turntables of cast iron or of strong steel construction are recommended. Light turntables soon become useless. Rails should be sunk in the floor or, if raised, the doorway should be provided with thresholds to avoid introducing uncontrolled air.

Where a "Single Subur" is being built and will not be extended to form a "Double Subur", the turntables can be replaced by switches. More space is needed, but the trolleys can be given a longer wheelbase, which improves their stability.

Bars *(Beroties)*

The sheet should be hung on the trolleys on separate detachable bars. Racks consisting of several bars fixed together are not recommended, as they sometimes warp or break. The bars should fit on to the trolleys crosswise, *i.e.* at right angles to the rails, and should be placed with their centres not less than three inches apart. Even spacing of the bars can be ensured by means of distance pieces or by notches in the side bars of the trolleys. It is generally better not to place bars lengthwise on the trolleys, as this might hamper the circulation of smoke and thus result in local overheating of sheet hanging directly over the flues.

Notes on Operation

Thickness of Sheet

The most suitable thickness for wet sheet to be dried in a "Subur" Smoke House in the proper period of four days, is between one-tenth and one-eighth of an inch.

Drying of Sheet

In order to dry sheet quickly and efficiently a comparatively low temperature and ample ventilation are required in the early stages. Thereafter higher temperatures are necessary, with reduced ventilation. If the sheet were kept in one chamber all the time it would be difficult to fulfil these conditions. Therefore the procedure is first to allow the fresh sheet to drip under shelter for three or four hours and then to put it into the coolest chamber, which is the one farthest from the furnace. Here it receives full ventilation, a good draught of air being necessary to carry off the large amount of moisture which is given up during the first few hours. From this first chamber, the sheet is moved into the next chamber on the next day, and so on until on the fourth day

it is in the hottest chamber, nearest the furnace, and becomes completely dry.

Control Settings

Some practice is usually required before the ventilators and smoke outlets can be set so that the proper temperatures are maintained in the various chambers and the drying programme is correctly followed. Once the correct settings are found, little alteration is required in normal working and the smoke-house can then be operated easily, chiefly by regulating the stoking of the fire.

The following recommended settings are only approximate, since all smoke-houses do not behave in the same way, but they show the general idea and will serve as a starting point for any one commencing to use a "Subur" Smoke-house.

1st Chamber (farthest from furnace).

Temperature	100°F for first three hours, rising to 110°F to 115°F
Flue Outlets	Three quarters to fully open
Bottom Ventilators	Fully open for first three hours, and then reduced to half open
Top Ventilator	Fully open

2nd Chamber

Temperature	120°F to 125°F
Flue Outlets	About one quarter open
Bottom Ventilators	Half open
Top Ventilator	Half open

3rd Chamber

Temperature	130°F to 140°F
Flue Outlets	One quarter open
Bottom Ventilators	Very nearly closed
Top Ventilator	One quarter open

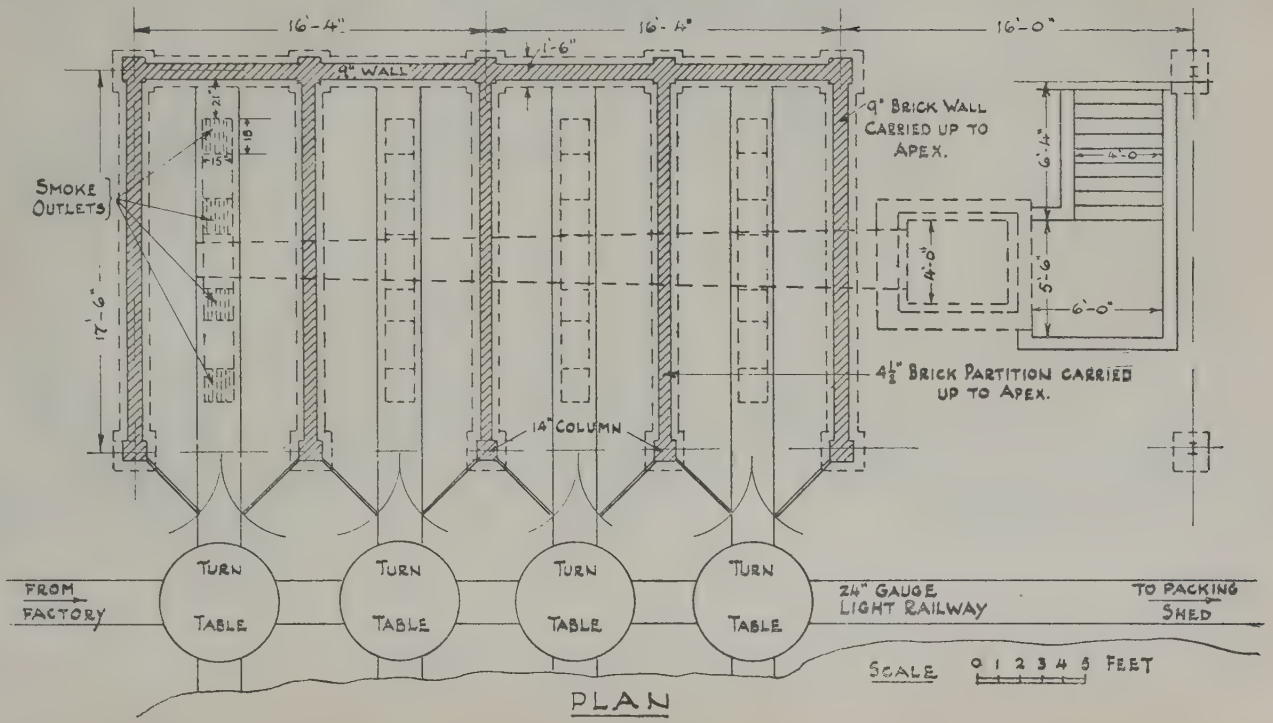
4th Chamber

Temperature	140°F to 145°F
Flue Outlets	Very slightly open
Bottom Ventilators	Closed
Top Ventilator	Very slightly open

Fuel

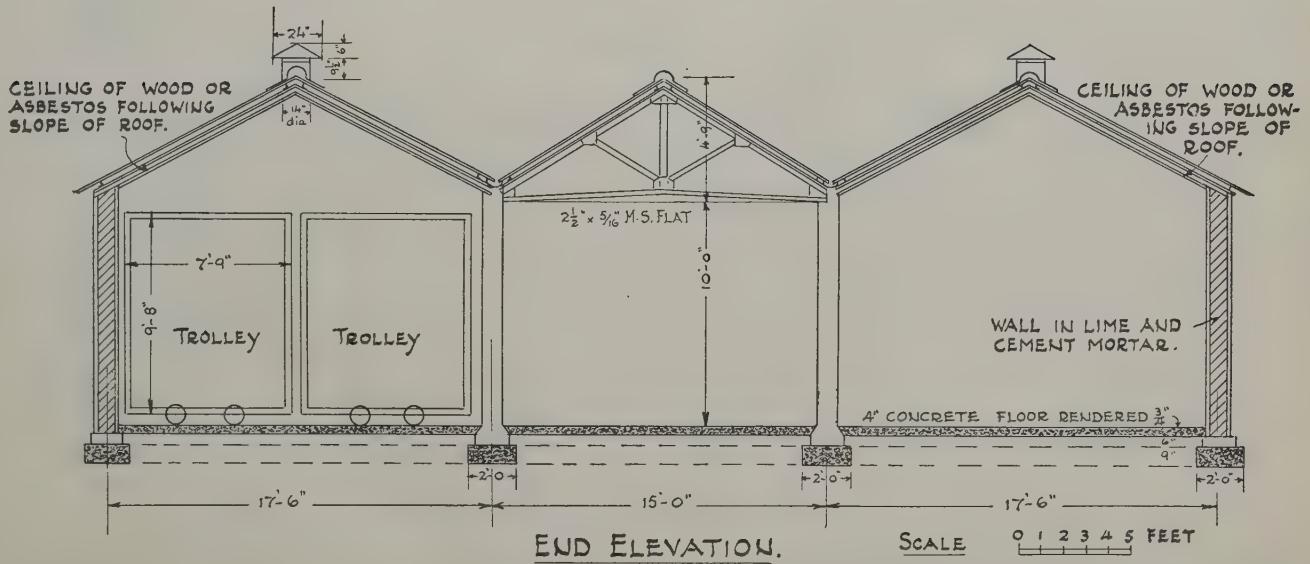
A mixture of jungle and rubber wood is better than rubber wood alone. If jungle wood can be obtained easily, equal parts of each should be used. Burning rubber wood alone often results in the smoked sheet being paler than is now desired.

"SUBUR" TYPE SMOKE HOUSE



PLAN

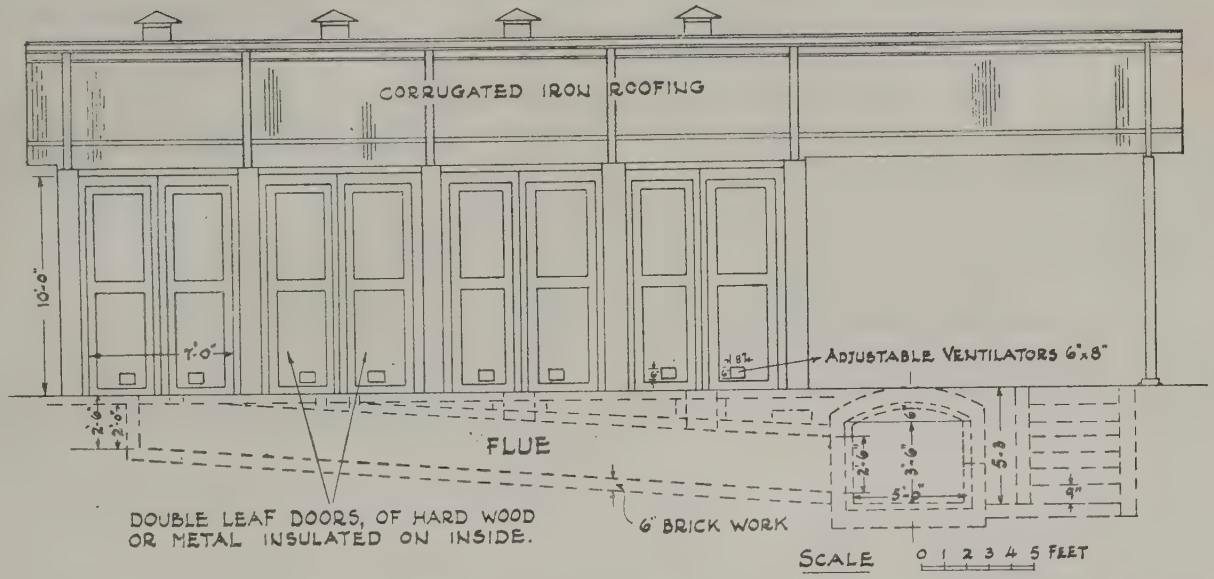
"SUBUR" TYPE SMOKE HOUSE



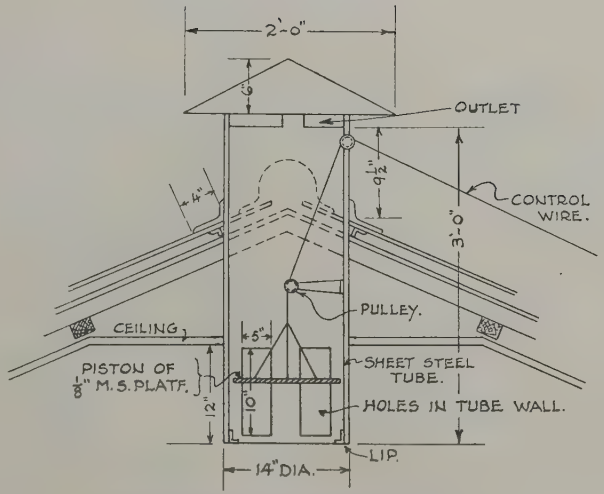
END ELEVATION.

SCALE 0 1 2 3 4 5 FEET

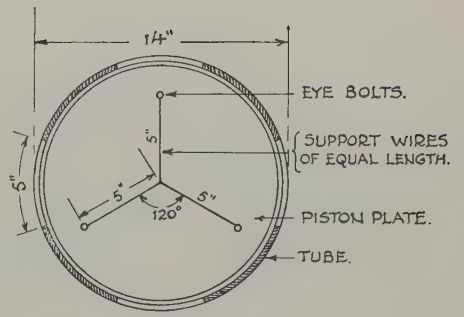
"SUBUR" TYPE SMOKE HOUSE.



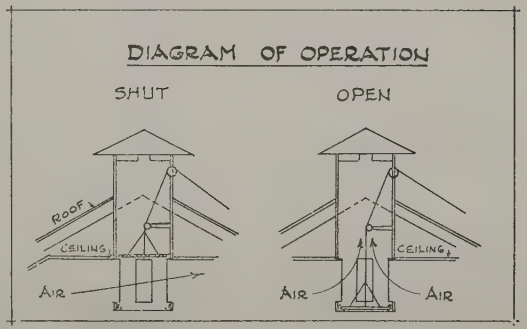
SECTIONAL ELEVATION.



SECTION OF ADJUSTABLE "PISTON" TYPE VENTILATOR



PLAN OF PISTON



(B) THE MODIFIED TYPE WITH FURNACES AND FLUES ABOVE GROUND LEVEL

Notes on Design

"Single-Sided"

The unit of construction is a building divided into four chambers and heated by two furnaces. The furnaces have their floors on ground level, or slightly below it if practicable. They are placed close to the rear wall of the building and each furnace has two flues. Each flue serves one chamber. The trolleys carrying the sheet run astride of these flues, the tops of which are about two feet above the level of the floor.

There is a verandah along the front, to provide shelter for dripping and inspection, and the furnaces at the rear are protected by a continuation of the main roof.

"Double-Sided"

This again consists of two single-sided buildings joined by a central verandah which serves both.

Drying Time

As in the original type of building, the drying time of sheet not over one-eighth of an inch thick is less than four full days.

Capacity

Each chamber of the size shown in the diagrams holds two trolleys, and each trolley carries about 900 lb. of sheet, giving a daily output of 1,800 lb., dry weight, from a four-chambered building. The capacity is thus similar to that of the original type.

Flexibility of Design

The dimensions shown on the diagrams are for a building of convenient size, but can easily be altered to suit smaller or larger crops. Also, where the crop is small now but will increase later, only four—or even only two—chambers need be built at first, and other pairs added as required.

Division into Separate Chambers

As in the original type of building, the quickest drying, with least fuel consumption, is obtained when each day's crop is kept separate. This means, in practice, that as drying proceeds the trolleys must be moved from one chamber to another each day.

Less moving would be necessary if some of the partitions were left out. Fuel consumption might be increased, and there would be the danger of prolonging the drying time beyond four days.

Notes on Construction

Flue and Smoke Outlets

The flues are covered by loose concrete slabs which can be lifted to permit cleaning. Smoke outlets are in the sides and near the top, and are covered with coarse gauze or perforated steel plates. To obtain a good distribution of smoke, and to prevent local over-heating of the sheet in the centre, spreaders consisting of perforated steel plates are carried on the trolleys.

Along the top of each flue is an air duct formed by more loose concrete slabs, which ensures that some of the ventilating air is pre-heated before being released into the chambers. This also serves to prevent the top of the flue itself from becoming dangerously hot.

Details of the flues, smoke outlets, and air ducts are shown on the accompanying diagrams.

Furnace Doors

As in the original type, these should preferably be counter-poised cast iron plates, sliding vertically and fitted with adjustable ventilators.

Ventilation

In addition to the pre-heated air which enters through the air ducts above the flues, more ventilating air is required. This is admitted through adjustable ventilators at the bases of the rear wall, door, and ends of the building. Such ventilators should be about 9 ins. × 6 ins., fitted with horizontally-sliding covers and placed as shown in the diagrams.

Top ventilators should be as described for the original type of "Subur" smoke-house.

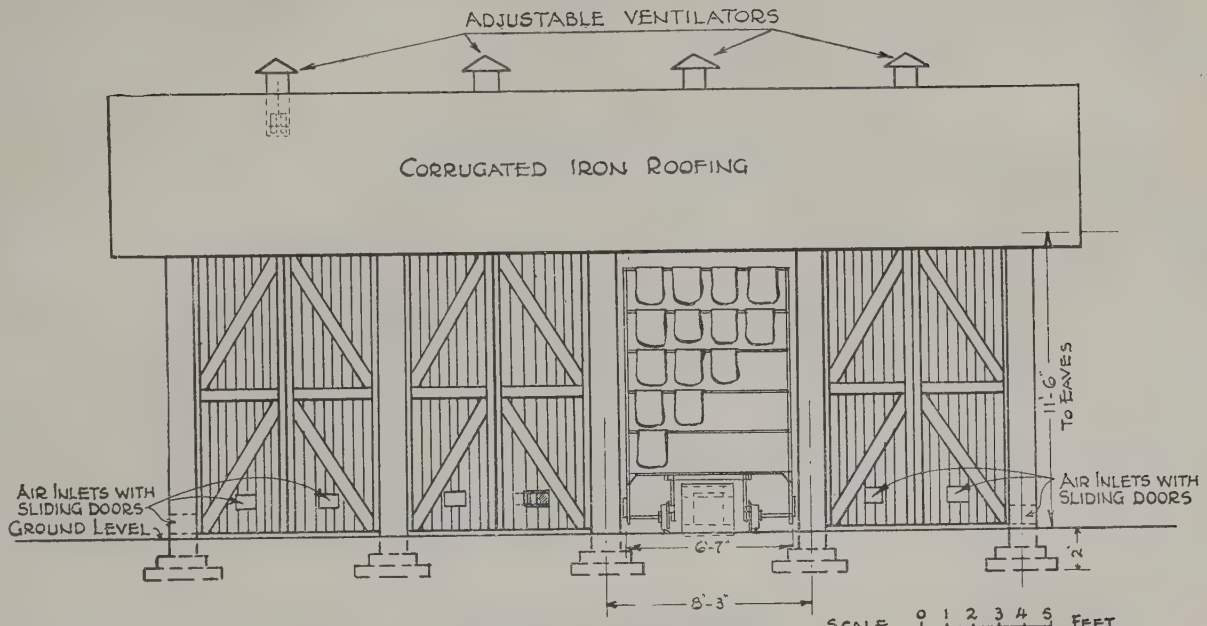
Doors, Inspection Window, Roof, Walls and Bars *(Beroties)*

Notes for these are the same as in the case of the original type of "Subur."

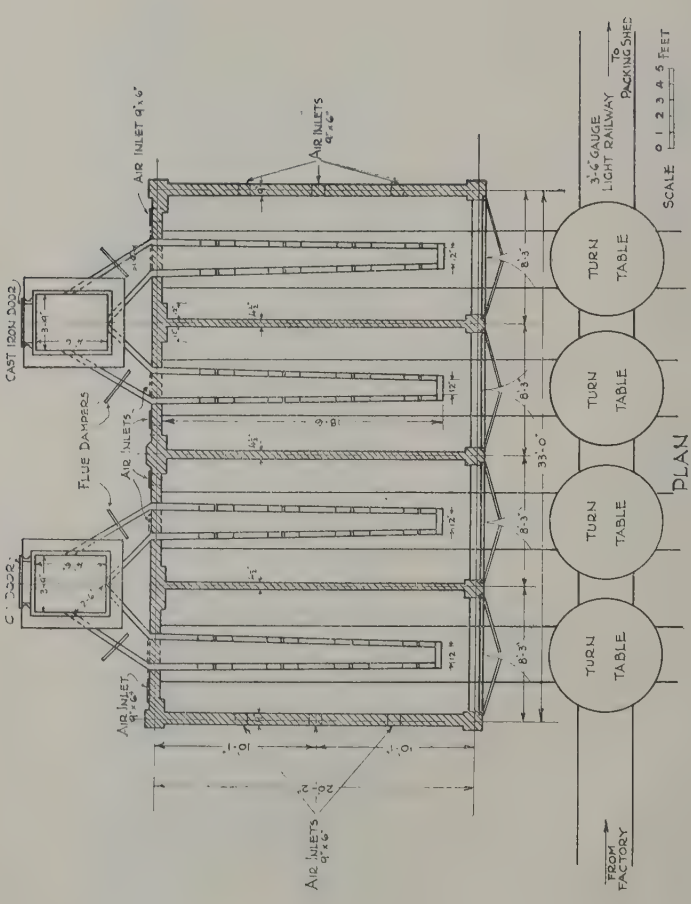
Trolleys, Turntables and Rails

These are similar to the original "Subur," described above, except that, because the flues are above ground level, the trolleys

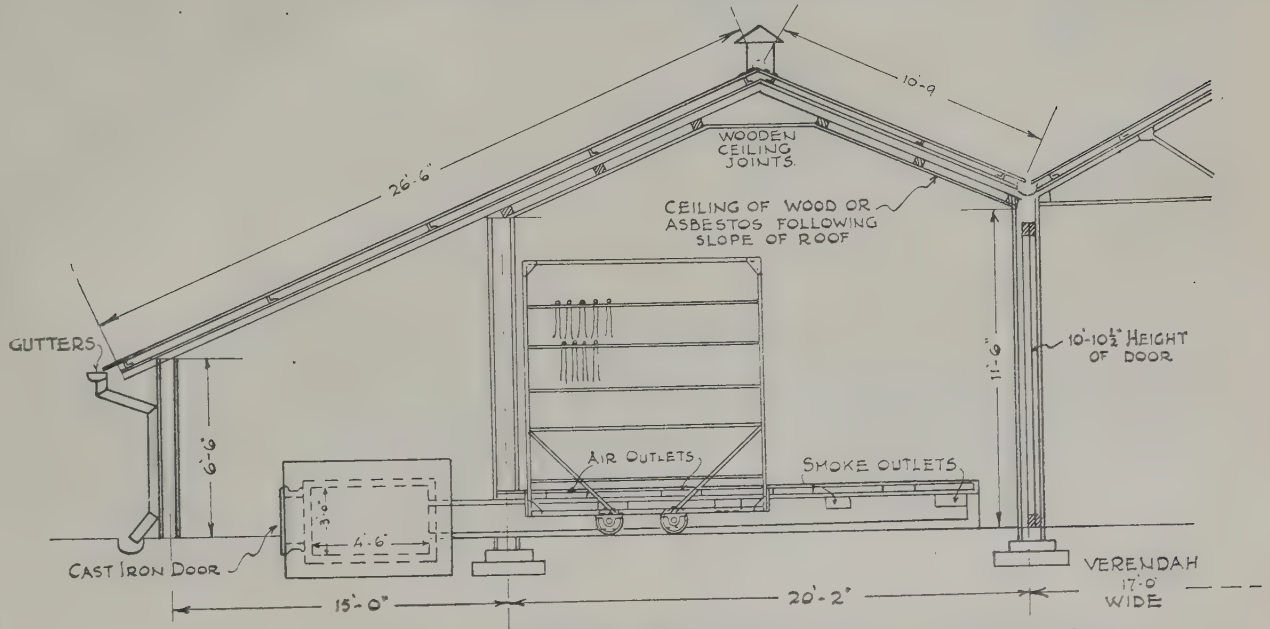
MODIFIED "SUBUR" SMOKE HOUSE.



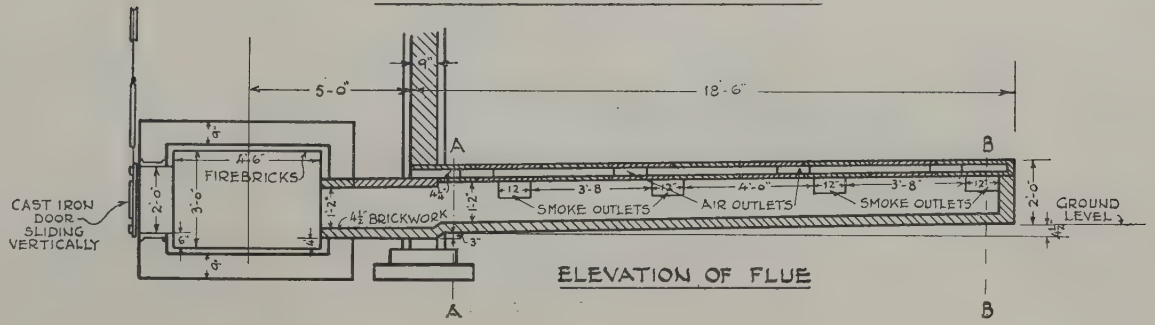
FRONT ELEVATION

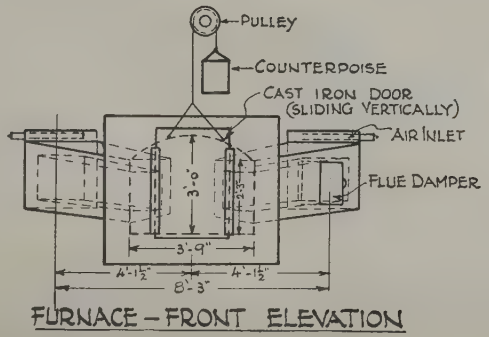

CAST IRON DOOR
FLUE DAMPERS
AIR INLETS
AIR INLET 9"x6"
AIR INLETS 9"x6"
AIR INLETS 9"x6"
TURN TABLE
TURN TABLE
TURN TABLE
TURN TABLE
33'-0"
3'-6" GAUGE LIGHT RAILWAY
FROM FACTORY
TO PACKING SHED
SCALE 0 1 2 3 4 5 FEET
PLAN

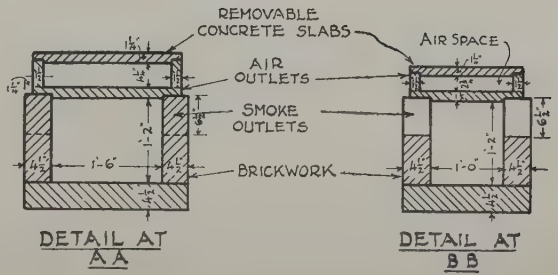
MODIFIED "SUBUR" SMOKE HOUSE.



CROSS SECTION.


MODIFIED "SUBUR" SMOKE HOUSE
5'-0"
18'-6"
9"
A
B
FIREBRICKS
4'-6"
3'-0"
2'-0"
CAST IRON DOOR SLIDING VERTICALLY
4½ BRICKWORK
SMOKE OUTLETS
AIR OUTLETS
SMOKE OUTLETS
GROUND LEVEL
ELEVATION OF FLUE


PULLEY
COUNTERPOISE
CAST IRON DOOR (SLIDING VERTICALLY)
AIR INLET
FLUE DAMPER
3'-0"
3'-9"
4'-1½"
4'-1½"
8'-3"
FURNACE – FRONT ELEVATION


REMOVABLE CONCRETE SLABS
AIR SPACE
AIR OUTLETS
SMOKE OUTLETS
BRICKWORK
1'-6"
1'-0"
DETAIL AT A A
DETAIL AT B B

are built to run "astride" them. This means that a wider gauge track, 3 ft. 6 ins., is necessary, and the trolleys must be higher if they are to carry the same load. Owing to the difficulty of loading high trolleys, it is not advisable to have them more than 10 ft. 6 ins. in height.

Notes on Operation

The modified type of "Subur" smoke-house can be operated in the same way as the original type, in which all the loaded trolleys are moved each day. Since, however, in the modified "Subur" each chamber has a separate flue and damper, thus making temperature control much easier, it is suggested that each day's crop be kept for two days in an end chamber and two days in an inner one. In this way the loaded trolleys would only need to be moved once in the course of drying, instead of three times. The flue dampers and air inlets should be adjusted daily in each chamber to give the temperatures and degrees of ventilation recommended for the working of the original type of "Subur."

Conclusion

In conclusion it is desired to acknowledge the valuable work done by engineers and contractors and estate managers in the development of both the original and modified types of "Subur" smoke-houses.

Kuala Lumpur,

February, 1937.

NOTE

ON AN

INEXPENSIVE TEMPORARY SMOKE HOUSE

BY

A. Moore

During the last two years the Institute has been recommending to small-holders a very cheap, but effective, smoke-house. It is easily built of common materials, and no skilled labour is necessary. The cost of construction is about $4 if the owner does the work himself and can obtain bamboos etc. free, or about $8 if all labour and materials have to be paid for. This smoke-house was fully described by Eaton in this *Journal*, Volume 6, No. 1, August 1935. Models have been exhibited at many local Shows, and many number of such smoke-houses are now in use on small-holdings throughout Malaya.

The original size of smoke-house, suitable for most small-holdings, holds only about 60 sheets, equivalent to 80 or 100 lb. of rubber. This is too small for estate use. It has, however, been found that larger smoke-houses of ten or twenty times this capacity, built on the same lines, will work successfully. They cost thirty or forty dollars each, and last for a year or more.

On estates they have proved very useful as temporary smoke-houses pending the construction of a large permanent one. For example, on newly-opened estates where it is desired to defer the building of a permanent smoke-house until the daily crop has reached a certain figure, cheap temporary smoke-houses can be used. Also, where an estate smoke-house has been destroyed by fire sufficient of these temporary ones to deal with the crop can be built within a couple of days, and production is almost uninterrupted.

The construction of a temporary smoke-house to hold about 1,600 lb. of sheet (dry weight), is shown on the accompanying diagrams. The photographs show two of these which are in regular use on the Institute's Experiment Station at Sungei Buloh. Each one cost $35. The drying time for sheet under one-eighth of an inch thick is four to five days.

The smoke-house consists of one room. The framework is of rough timber, and the walls and roof are of split bamboos lined with strong paper. Other materials suitable for the walls and roof are sacking treated with tapioca starch, or split *nibong* lined with strong paper. Boards could of course be used, but would add considerably

to the expense. The smoke-house is heated by means of a fire inside the building. Half of an old oil drum makes a suitable firebox, over which is hung a sheet of corrugated iron to act as a baffle plate. The lower parts of any posts near to the fire should be protected by metal sheaths. The ventilators consist of holes about 12 ins. × 6 ins.; one at the base of each wall and two near the ridge of the roof. They should be provided with adjustable covers.

To protect it from the weather, the smoke-house is provided with an outer roof of attaps, raised about a foot above the top of the smoke-house proper. This outer roof can be carried on the corner posts of the smoke-house, or may be built with its own supporting posts in the form of a separate shed.

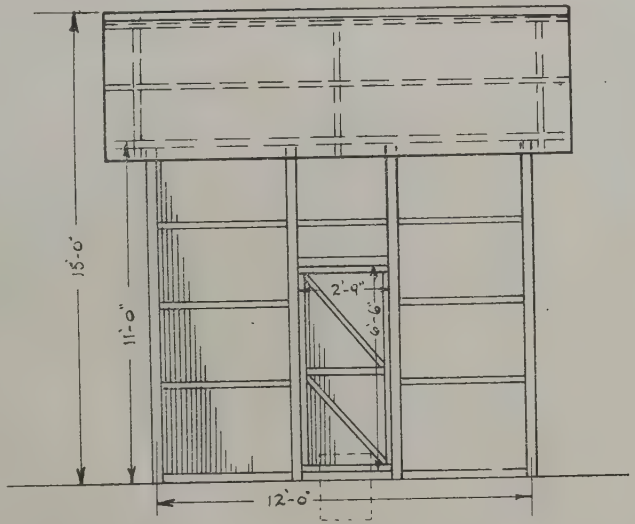
To sum up, a very inexpensive smoke-house, lasting a year or more and holding about 1,600 lb. of sheet, can be built for $35. The drying time is four to five days; so that five of these smoke-houses would deal with a crop of 1,600 lb. per day, which is the crop of an estate of a thousand acres. The chief disadvantage of these cheap, temporary smoke-houses is that operating labour costs are high compared with modern smoke-houses of, say, the "Subur" type. There is also a greater risk of fire, and the fuel consumption is heavier. They are, however, valuable as temporary smoke-houses on estates, and might even be used for long periods if desired.

Kuala Lumpur,

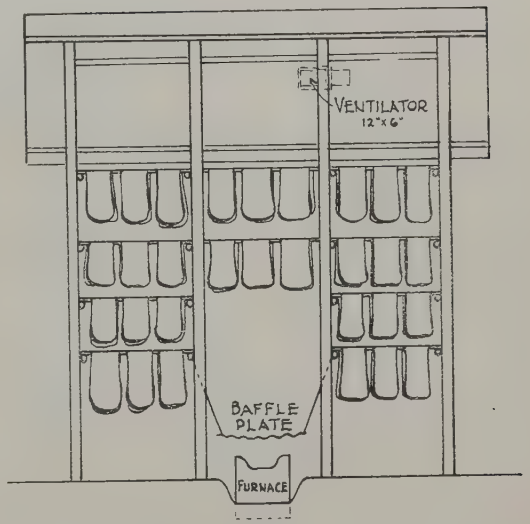
9th February, 1937

TEMPORARY SMOKE HOUSE

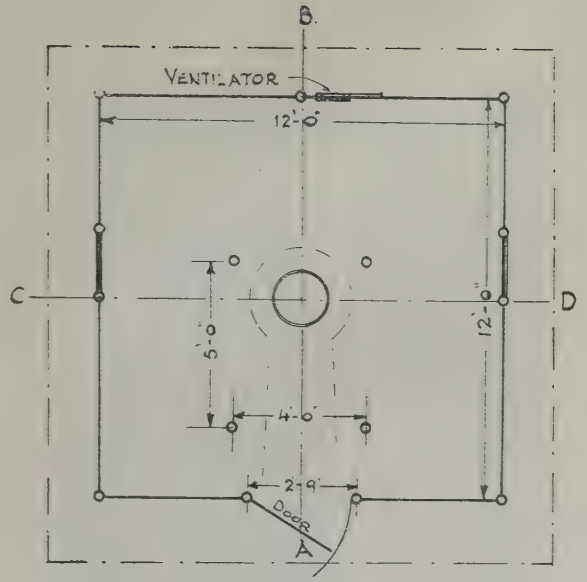
COST ABOUT $35 — CAPACITY ABOUT 1,600 LB. OF SHEET — DRYING TIME 4-5 DAYS



FRONT ELEVATION

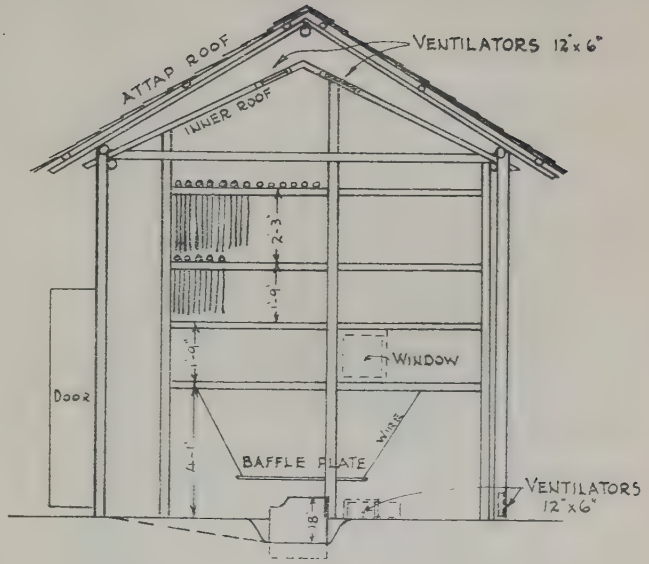


SECTION C. D.



GROUND PLAN

Posts—Bamboo or Rough Timber
Beroties—Light Bamboo or Bertams



SECTION A. B.

Walls and Inner Roof—Split Bamboo lined with paper, or Sacking treated with Tapioca paste

PLATE I

Front view of temporary smoke house. Walls and inner roof are of split bamboo lined with paper.

PLATE II

End view of building shown in Plate III.

PLATE III

View of two temporary smoke houses built side by side with a passage between. They can be used independently of each other.

PLATE IV

Interior view showing furnace. Note the paper lining to the wall.

NOTES

ON

CENTRIFUGAL CONCENTRATION OF LATEX

BY

J. H. Piddlesden

The concentration of latex by the use of a centrifugal machine of the cream-separator type was patented by Utermark in 1923, and from that date there has been a continuous commercial and technical development of the process. Although latex bears certain similarities to milk, in that they are both emulsions, and in each case the lighter disperse phase has a somewhat similar density and particle size, latex has proved more difficult to separate into cream and skim fractions, and has necessitated the development of special machines for the purpose. As would be expected, these machines are largely modifications of the cream separator.

Design

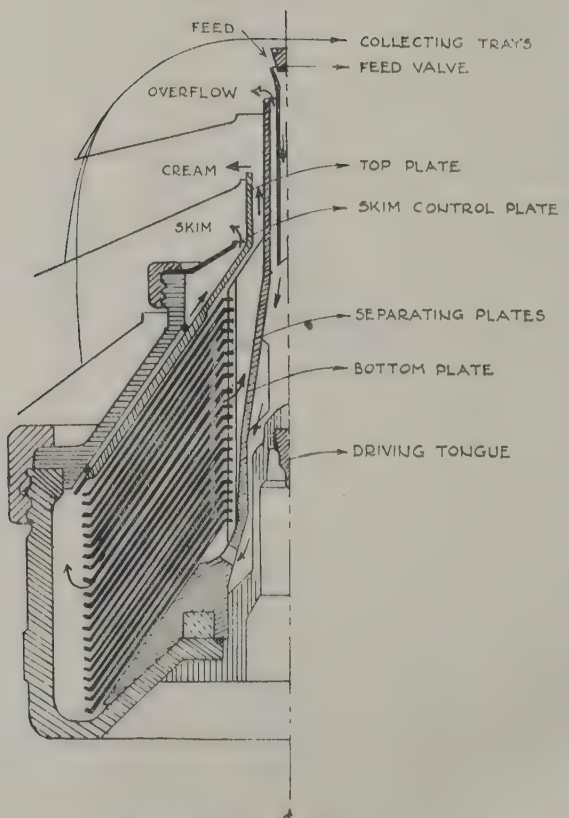
The centrifugal machines commonly used consist essentially of a bowl of approximately 10 inches diameter, rotated at 6,000 to 8,000 revolutions per minute. The interior of the bowl is filled with a pile of conical plates between which there are narrow gaps. The latex is introduced at the bottom of the bowl by a central feed tube and ascends through perforations in the plates. As the latex passes up through the plates separation occurs, owing to centrifugal force, and the portion richer in rubber passes up through the gaps between the plates, towards the centre of the bowl. The fraction containing less rubber passes down through the gaps in the opposite direction. It then rises through the annular space between the edge of the plates and the bowl. Both streams are brought back to concentric spaces round the feed tube and discharged at different levels into collecting trays.

Fig. 1 is a diagram of a typical bowl.

Preservatives

It is obviously necessary to add some form of preservative to the latex, to prevent coagulation in the bowl, and subsequently to keep the concentrate fluid. Many substances have been tried but

Figure 1



DIAGRAMMATIC SECTION
OF
HALF BOWL

ammonia appears to be the only successful one in common use. It has the following advantages :-

a. It will keep latex in a fluid condition and free from putrefaction almost indefinitely.

b. It reduces the viscosity of the latex.

c. It is completely volatile and leaves no harmful solid residue in the finished rubber goods made from the concentrate.

d. It is comparatively cheap.

e. It is easy to use, as it is bubbled into the latex in the form of a gas, and very little mixing is required to get a uniform distribution throughout the liquid. It is extremely difficult to mix a solid directly into latex, and if a solid preservative is used it must be dissolved in water before mixing. This has the disadvantage of diluting the latex, and more prolonged stirring than is necessary with ammonia is still required.

The disadvantages of ammonia are that it imparts an increased corrosive action to the mixture, and renders the skim difficult to dispose of economically.

It has been found in practice that 0.2 per cent of ammonia is sufficient to prevent coagulation and to provide a viscosity low enough for centrifuging, provided that the latex is passed through the machine within 24 hours of collection and preservation. Larger quantities do not appear to facilitate the separation, and there are several advantages in keeping the proportion of ammonia low. The loss of ammonia in the machine is reduced, which not only saves money but renders the machine less objectionable to operate. Also the ammonia in latex may be regarded as being in solution in the water phase, and when separation occurs a large proportion of the ammonia remains in the skim fraction. Its presence here is a disadvantage, as it renders subsequent coagulation difficult. Finally the corrosive action is reduced by diminishing the concentration of ammonia. Table I gives comparative results obtained at the Institute with identical machine settings on latices containing different amounts of ammonia, and confirms the above conclusions regarding the amount of ammonia which is adequate.

When such small initial quantities of ammonia are used it is important that more ammonia be added to the concentrate as soon as possible after its production. The quantity necessary for prolonged preservation of the concentrate is 0.5 per cent. There are however indications that storage of the latex for a longer period than 24 hours before passing it into the centrifuge has certain advantages. The operation of the machine is usually smoother, and some of the sludge is removed by sedimentation before the latex enters the bowl. If a storage period of 48 hours is adopted, more than 0.2 per cent of ammonia is required to preserve the latex. The

final choice between these alternatives would depend upon the factory organisation and the characteristics of the actual machine used.

TABLE I

Centrifugal Concentration of Latices with varying Ammonia-contents

Run No.	Feed			Cream	Skim	Efficiency*
	Age Days	D.R.C. per cent	NH_3 per cent	D.R.C. per cent	D.R.C. per cent	per cent
P. 147	0	34.9	0.13	58.1	9.7	86.1
P. 152	0	34.8	0.15	57.7	9.5	88.0
P. 148	0	33.9	0.32	60.2	9.5	86.4
P. 153	0	35.8	0.28	57.7	13.0	83.6
P. 146	1	29.2	0.33	60.1	13.1	70.5
P. 154	1	36.0	0.27	61.1	14.4	79.5
P. 150	0	34.4	0.58	57.9	10.5	81.7
P. 155	0	33.8	0.58	60.2	11.5	81.1
P. 149	1	33.4	0.62	59.9	15.9	71.1
P. 151	1	34.8	0.58	60.9	13.7	78.8

** "Efficiency" is the proportion of the total rubber in the cream fraction.*

Operation

The object of centrifuging is to obtain a concentrate containing at least 58 per cent of rubber. A skim fraction is inevitably obtained as a by-product, and this is an important factor in the commercial consideration of the process. The ideal would be achieved if the rubber content of the skim were low enough to make recovery uneconomic. At present it appears to be impossible to achieve this ideal. It is obvious that the larger rubber particles are those most readily separated from the serum; hence, when partial separation has occurred, the rubber remaining in the serum is in the form of extremely fine globules. To remove these from the serum would require a greatly increased separating force. This can be obtained by the use of a bowl of larger radius or a higher velocity, both of which would increase the mechanical difficulties in the construc-

tion of the machine, and would thereby increase the initial cost. Cost is not the only objection to this remedy. It is extremely difficult to increase the separating force applied to the skim towards the end of the separation, without disturbing the equilibrium throughout, and simultaneously applying increased separating force to the cream. Most machines are however provided with adjusting devices, by means of which the concentrations and relative proportions of the products can be controlled to some extent.

Tests with Machines at the Rubber Research Institute

Two types of machine have been tested experimentally in the Rubber Research Institute. The first was a very small laboratory model in which quantities of the order of one gallon of latex were treated per run. The feed rate was controlled by the provision of interchangeable jets, and the skim passages contained grub screws by which they could be obstructed to a varying degree. With the settings most suitable for high dry-rubber-content in the concentrate, it was found possible to obtain cream containing 66 per cent of rubber. Similarly with modified settings the rubber-content of the skim could be reduced to 8 per cent. These values could not, however, be obtained simultaneously, nor could either be produced without using an extremely low feed-rate. The best average setting giving a reasonably high throughput-rate, gave cream of 54 per cent together with skim of 14 per cent dry-rubber-content. The cream formed 53 per cent of the input-volume and contained 81 per cent of the total rubber.

The second type tested was a full-scale machine capable of treating 60 gallons of latex per hour. This had independent adjustments for the cream and skim outlet channels. The latter took the form of a series of interchangeable discs, by means of which the size of the annular aperture through which the skim was discharged could be varied. A larger aperture increased the proportion of the total volume discharged as skim, and its dry-rubber-content. It also increased the throughput-rate of the machine. The adjusting devices provided for the cream-outlets consisted of nozzles screwed through the neck of the top plate. They could be set to project for different distances into the gap between this neck and the overflow-tube. Thus, as the cream ascended through this annular space, it could be drawn off at varying distances from the centre of the bowl. The feed-rate was controlled by a needle valve. These settings were interdependent in the sense that any alteration to the cream settings, designed to give a richer cream, gave simultaneously a richer skim and *vice versa*. Further, if the skim controls were adjusted to compensate for too rich a skim, a reduced throughput of latex resulted. It was thus possible to obtain a rich cream, or a low skim, fairly

readily, but attempts to produce both at the same time were not very successful.

Table II gives a typical selection of results illustrating these points.

TABLE II

Centrifugal Concentration of Latex: Variations in Throughput, Concentration of Cream and Skim, and Efficiency

No.	Throughput (gals. per hour)	Cream D.R.C. per cent	Skim D.R.C. per cent	Efficiency* per cent
1	66.3	51.1	6.0	95.5
2	62.5	61.4	12.3	76.5
3	53.0	52.5	7.0	95.4

** "Efficiency" is the percentage of the total rubber which appears in the cream fraction.*

In the first example a test was made, with arbitrarily selected settings. In the second, the cream-outlet nozzles were screwed further into the neck of the top plate with the object of increasing the rubber-content of the cream. This was achieved, but it is seen that the rubber-content of the skim was also increased and the efficiency reduced thereby. In the third case, the cream-settings were left as in example 2 but a different disc designed to give skim containing less rubber was used. This reduced the rubber-content of both skim and cream. The rate of flow through the machine was also diminished, but the efficiency rose to its initial high value.

One of the main reasons for this difficulty in obtaining simultaneously a rich cream and a poor skim, is almost certainly the rapid increase in viscosity which occurs with increasing concentration.

The following Table III due to Rhodes (1) illustrates the magnitude of this factor.

The upper limit of concentration has been stated (2) as 73 per cent total solids, at which the latex practically ceases to flow. Another author (3) states 67 per cent total solids as the approximate upper limit for a centrifugal machine. Any increase of the dry-rubber-content of the cream leads to reduction of flow in the concentrate-passages inside the bowl. This in turn causes increased separation by keeping the material in the bowl for a longer time. Thus the passages soon tend to become filled with a thick buttery

TABLE III

Dry Rubber Content and Viscosity of Latex

D.R.C. per cent	* Viscosity (centipoises)
30.2	3.46
55.9	23.72
60.9	51.94—Normal Concentrate
66.2	159.50
67.9	557.60
70.8	2160.00

* *These results were obtained on latex concentrated by filtration. This method of preparation gives a concentrate similar to that produced by a centrifugal machine.*

cream and frequent cleaning is necessary. In the larger machine used in these experiments, attempts to produce cream with a rubber-content appreciably above 60 per cent. caused rapid choking. It was also found that the only way in which cream of not less than 60 per cent rubber-content, together with skim containing less than 8 per cent rubber, could be produced, was by reducing the feed-rate to approximately 30 gallons per hour. This again resulted in rapid choking for similar reasons.

The best average setting for the machine gave cream containing 60 per cent, together with skim containing 10 per cent of rubber, when latex was fed in at the rate of 50 gallons per hour. Under these conditions equal volumes of skim and cream were produced, and the latter contained 86 per cent of the total rubber. Even with these settings, the throughput began to fall off after the machine had been run for less than half an hour, and 80 gallons was the maximum quantity which could be treated before choking with thick cream made dismantling for cleaning necessary.

Attempts were therefore made to develop an alternative method of operation. By increasing the feed-rate or reducing the bowl-speed a lower separating force was applied and a satisfactory cream could be produced with less risk of over-concentration and choking of the passages. In this case, however, a much lower proportion of the total rubber was obtained as concentrate and a large quantity of fairly rich skim (dry-rubber-content 15–20 per cent) was produced. At first sight this presents the attractive possibility of being able to produce at one and the same time a latex-concentrate and a skim of a consistency suitable for the manufacture of sheet rubber. This was not realised, since the skim from centrifugal concentration does not lend itself to the manufacture of first-quality rubber. The reasons for this are discussed below.

Recovery of Rubber from the Skim-fraction

A skim-fraction containing 6 per cent to 8 per cent of rubber differs from normal latex diluted to a similar dry-rubber-content in that the average size of the particles is much smaller, it contains ammonia, and it also contains a very large proportion of the non-rubber constituents of the latex from which it was made. Each of these factors tends to make coagulation difficult and expensive, particularly if an acid coagulant is considered. The use of magnesium chloride and sodium silicofluoride, as a coagulating mixture, gives better results (4), but even when this is used a coagulum suitable for the manufacture of normal smoked sheet is very difficult to obtain. Such coagulum can however be made into crepe with less difficulty. In practice, although the machining cost is higher, crepe is probably the more desirable product, since in its manufacture the rubber is submitted to a more efficient washing than is the case with sheet, and a large proportion of the water-soluble serum constituents are thereby removed.

If skim containing a higher proportion of rubber (15 per cent—20 per cent) is produced, in the manner described earlier, the same difficulties still apply. This material can be coagulated with acid, but excessive quantities are required and the coagulum cannot be rolled into sheet. By using a suitable magnesium chloride—sodium silicofluoride mixture a coagulum is obtained which can usually, but with difficulty, be handled in an ordinary sheeting battery. The resulting sheet is liable to contain excessive quantities of serum constituents, which render it difficult to dry. It has also the unfortunate characteristic of assuming a very dark colour during smoking and it has been found in practice that brokers penalise it for the so-called defect of "oversmoking." These difficulties, coupled with the fact that the production of a serum rich in rubber necessitates a much lower yield of cream from a given quantity of latex, tend to rule out the possibility of an estate being able to produce simultaneously a latex concentrate, and with it first-grade sheet rubber derived from the skim fraction.

Commercial Practice

The present trend of machine design and published information on the process, both indicate that the usual object is to produce the maximum quantity of cream of suitable rubber-content, while regarding the production of skim as a necessary evil. For example Noble (3) states that a serum containing 6—8 per cent rubber is generally desirable on estates and quotes an analysis of the products of centrifugal concentration which is presumably typical of modern commercial operation and from which the following figures were culled :

	Skim	*Concentrate*
Total Solids	11.0 per cent	61.5 per cent
D.R.C.	7.1 per cent	60.0 per cent

Assuming that normal latex of about 35 per cent dry-rubber-content was the starting material, these figures indicate that the resulting cream formed slightly over half the volume of the initial latex, and contained roughly 90 per cent of the total rubber.

These results are superior to those obtained with the machines tested by us which were of types not in general use. The differences in performance, therefore, are probably due to modifications of machine design. It would appear from recent patents that the object of designers is to produce a machine of high separating power in which choking is overcome by a special arrangement of cream passages.

Materials of Construction

It is well known that latex preserved with ammonia exerts a corrosive action on most metals. Our own experience has shewn that the main attack in a centrifugal machine occurs on the plates. In the larger machine tested at the Institute, tinned iron plates were used and in the other the plates were of aluminium, but neither material can be recommended for a long working life. The corrosion itself is comparatively slow, but is accelerated by the cleaning which is so frequently necessary, with the result that aluminium plates were sufficiently damaged to render them ill-fitting after one year's use. Portions of the tinning were removed from the coated iron plates after only a few months' use. This is a serious defect, since when once the protective film on tin-plate is pierced, corrosion due to electrolytic action occurs more rapidly than with iron not tin-coated. The corrosion of the heavy steel bowls is not sufficiently rapid to curtail their working life.

There is another aspect of this corrosion problem which is of even greater importance to the producer of latex concentrate than deterioration of the machines. This is the contamination of the latex by the traces of metallic salts formed by corrosion. These remain in the latex and many have extremely deleterious effects on the rubber. Recent work by Hastings (5) and others has shewn that minute traces of copper are particularly harmful, and that ammoniated latex which has been in contact with copper or brass for only a very short time will yield a rubber which shews bad resistance to ageing.

Iron is also attacked by ammoniated latex. In this case the effect on articles made from the latex is less serious, but it is very apparent on the latex itself. Traces of iron cause discolouration by the formation of sulphide in latex preserved with ammonia, and render it undesirable for some purposes.

The ideal material for the construction of a centrifugal machine for latex concentration is stainless steel. Unfortunately it is ex-

pensive. Steel may be used as a compromise, but great care should be exercised to ensure that no part which comes in contact with the latex is constructed of copper or brass, or even of either of these metals coated with tin, since the protective film very soon wears off under the combined action of corrosives and frequent cleaning.

Summary

Tests were carried out with two different types of centrifuge and satisfactory latex concentrates were produced. The main difficulty with the machines under test was that they would produce only small quantities of concentrate before becoming choked. It is believed that similar difficulties have been experienced with other types of machine. It was found desirable to keep the quantity of ammonia used as preservative below 0.3 per cent.

The experiments failed to reveal any economic method whereby the skim fraction can be utilised for the production of smoked sheet.

Although the ammoniated latex used is only faintly alkaline, the conditions under which centrifugal machines operate make corrosion a serious problem, and it is therefore desirable to construct them from stainless steel.

Acknowledgments

The tests on the smaller machine referred to above were carried out by Mr. A. Moore and the writer is indebted to him and to Dr. E. Rhodes for their advice and help in the preparation of this paper.

Literature Cited

(1) Rhodes, E. Private Communication

(2) Chem. Engineers' Handbook—Perry (1934) Flowers, A. E. 1534

(3) Noble, R. T. Latex in Industry—*The Rubber Age* New York (1935) **59**

(4) Hastings, J. D. *J.R.R.I.M.* **5,** (1934), 351

(5) Hastings, J. D. *J.R.R.I.M.* **7,** (1936), 55

Kuala Lumpur,
14th January, 1937

NOTE

ON

PRESERVATION OF LATEX BY ACIDS

BY

Edgar Rhodes and K. C. Sekar

Introduction

This note describes the results of some purely empirical attempts to preserve field latex by the simple addition of acid. The common knowledge of the process of coagulation, and published researches thereon, do not encourage the view that acids might be used to maintain field latex in a fluid condition over long periods. Fullerton (1), in coagulation experiments, found that when latex containing 20 per cent by weight of rubber is treated with progressively increasing amounts of acid, the second liquid zone—which, with latex containing 4 per cent of dry rubber, occurs between the pH values 3.52 and 1.00—is barely if at all apparent. With undiluted field latex containing 35 per cent dry rubber, this second liquid zone is entirely absent; between the pH values 1.49 and 0.83 which represent amounts of added acid corresponding to 2 cc. and 30 cc. of NHCl per 100 cc. latex, coagulation is either complete or almost complete and no zone of complete dispersion is found. From these experiments it would appear very unlikely that by the addition of any acid to field latex, fluidity could be maintained. The results obtained in some such experiments with large amounts of acid are described below.

Experimental

Trials with Acetic Acid

Experiments were first made with latex diluted to a dry rubber content of 15 per cent. In Fullerton's *(loc. cit.)* experiments with such latex, the greatest amount of acetic acid applied was 8 cc. of the 2.5 per cent acid or roughly 1/5 cc. of the pure substance per 100 cc. of latex. With amounts of acid of this order, complete coagulation resulted. In the present experiments it was found that if the amount was increased to between 10 cc. and 20 cc. of pure acid per 100 cc. latex, no coagulation occurred and fluidity was maintained during an observation period of over three weeks.

When similar experiments were made with latices containing over 30 per cent dry rubber, however, coagulation or clotting resulted over a wide range of acid concentrations. Nowhere in the range which extended to 25 cc. of pure acid per 100 cc. of field latex was a zone of satisfactory fluidity observed.

Trials with Formic Acid

With this acid, fluidity zones were found both for diluted and undiluted field latex.

It was found that with latex diluted to a dry rubber content of 15 per cent, a fluid condition was maintained for over six weeks by the addition of amounts of 90 per cent formic acid lying in the zone 5—25 cc. per 100 cc. of latex.

With undiluted field latex, fluidity was maintained for the same period on treatment with between 7 and 25 cc. of 90 per cent acid per 100 cc. latex. The fluidity zone appeared however to be narrower with some latex samples than with others. In certain cases the upper limit beyond which coagulation occurred either immediately or in less than three days was found to be 15 cc. of acid per 100 cc. of latex. The amount giving the best general results was the equivalent of 10 cc. of 90 per cent acid per 100 cc. latex. Samples of field latex preserved with this amount of acid were found after six weeks storage to have no putrefactive odour; the latex also passed through a sieve having 100 meshes per inch without leaving measurable clots. There was, however, a noticeable lack of stability; when heavy frothing was induced by vigorous agitation the froth coagulated. Similarly, rapid stirring quickly induced coagulation in the body of the latex. After approximately eight weeks' storage in glass, a clear yellow serum began to appear in the lower layers of latex; shaking restored homogeneity but partial separation occurred again in approximately one week's time. This indicated almost beyond doubt that the acid-preserved latex was in a micro-flocculated condition, which would account in great measure for its comparative instability. It was found that the stability of the latex could be improved slightly by the addition of 1 per cent of saponin, calculated on the rubber phase of the latex. Curiously enough, casein had little if any stabilising effect. The saponin-"stabilised" latex, although less sensitive to added compounding solids such as sulphur and zinc oxide than the parent unstabilised acid latex, was nevertheless decidedly unstable.

Trial shipments to England of the simple and saponin-"stabilised" formic acid-preserved field latex in four-gallon lots were received and reported upon by the technical officers of the London Advisory Committee for Rubber Research. It was found

by these officers that with the simple formic acid latex, an appreciable amount of clotting took place on the walls of the containers during transit and that in the case of the saponin-"stabilised" latex the amount of clotting was almost negligible. Further confirmation of the Malayan observations on stability was forthcoming in the fact that the acid latices proved much too unstable for normal compounding in England.

Trials with Hydrochloric, Nitric and Tri-chloracetic Acids

Preliminary trials with abnormally large amounts of these acids on undiluted field latex have so far not resulted in the finding of zones of permanent fluidity for latices treated with them.

Discussion and Summary

It is shown that by the application to field latex of amounts of formic acid of the order of 9 per cent by weight of the latex, or 10 per cent by volume of the 90 per cent commercial acid, a product results which will retain its fluidity for long periods. It is, however, apparently micro-flocculated, and unstable. Because of their instability it seems unlikely that acid latices of this kind will find technical applications. The findings are in no way contradictory to those of Fullerton whose experiments on coagulation did not include trials with such large amounts of acid.

It is regretted that fuller experimental data cannot be given because most of the relevant records were destroyed recently by fire at the Institute. It is probable that a further study will be made, from which additional experimental data together with a possible explanation of the empirical observations given here may emerge.

Acknowledgment

The authors' grateful thanks are due to Messrs. G. Martin and W. S. Davey for the examination of the latex samples in the laboratories of the London Advisory Committee for Rubber Research (Ceylon and Malaya).

Literature Cited

(1) Fullerton, R. G. *Q.J.R.R.I.M.* **2** (1930—1931) 156

Kuala Lumpur,
15th March, 1937.

MALAYAN PATENTS RELATING TO RUBBER

PART III

BY

ARTHUR MOORE AND EDGAR RHODES

A list of Malayan patents relating to rubber, together with abstracts of the more important grants up to the end of 1932 has already been published in this *Journal* (1)—(2). The present publication consists of a list of the grants made from the end of 1932 to the middle of September 1936 and includes abstracts.

The list is divided into four parts as under:

Section 1 F.M.S. Grants of Exclusive Privileges.
End 1932 to September 1936.

Section 2 Registration of United Kingdom and other British Patents in F.M.S.
End 1932 to September 1936.

Section 3 S.S. Grants of Exclusive Privileges.
End 1932 to September 1936.

Section 4 Registration of United Kingdom and other British Patents in S.S.
End 1932 to September 1936.

Specifications of which abstracts are given are marked in the list by an asterisk.

The list of patents was compiled from the register of F.M.S. Grants, by the courtesy of the Commissioner of Trades and Customs, F.M.S., at Kuala Lumpur, and from the similar register in Singapore by the courtesy of the Colonial Secretary.

Section 1. F.M.S. Grants of Exclusive Privileges 1932–1936

Year Issued	Number of Grant	Name of Grantee	Title of Invention
1932	720	Browning	Self-contained fuel-lighter
"	724*	Schweizer	A new type of partition guide and holder for coagulating tanks
"	725*	Schweizer	Improvements in and relating to continuous sheet coagulating tanks
"	726*	Graham & Kendall	Rubber road carpeting
1933	727*	de Schepper	Method of and means for making and obtaining rubber in powdered form from dispersions such as latex, or from solutions

F.M.S. Grants (Continued)

Year Issued	Number of Grant	Name of Grantee	Title of Invention
1933	728	Hodges	Reinforced compounded rubber moulded buckets
,,	729*	Sime, Darby & Co., Ltd.	Improvements in and relating to coagulating tanks
,,	731	England	Firelighter containing rubber
,,	732	Hughes and The Liverpool Electric Cable Co., Ltd.	Improvements in or relating to rubber compositions and articles composed thereof
,,	733*	Reginato	Improvements in and relating to line-ahead rubber sheeting batteries
,,	734	The Avon India Rubber Co. and Swanborough	Improvements in or relating to valves for the retention of pressure within hollow articles
,,	737*	Socfin Co., Ltd.	Drying and/or smoking plant
,,	743*	Board of Rubber Research Institute of Malaya and Eaton	A new or improved process for the preparation of soft rubber
1933	744*	Board of Rubber Research Institute of Malaya and Eaton	Process for the preparation of unvulcanised India rubber in crumb or powder form
,,	746*	Gaisman	Improvements in or relating to the manufacture of plantation rubber products
,,	757*	Cochran and Footner	An improved machine for the rolling of coagulated latex
,,	758*	Naugatuck Chemical Company	Improvements in or relating to the treatment and creaming of rubber latex (Assigned to U.S. Rubber Co. 12.7.35)
,,	762*	Société Anonyme Septa	Improvements in and relating to the manufacture of rubber products
1934	764	Claessen	Improvements in and relating to the manufacture of rubber envelopes, bags, or like containers
,,	768*	Naugatuck Chemical Company	Improvements in or relating to creaming of latex (Assigned to U. S. Rubber Co. 12.7.35)
,,	770*	Savege	Improvements in and relating to presses for packing rubber and the like
,,	772*	Reginato	Improvements in and relating to connecting troughs between the rollers of rubber sheeting machines (Assigned to Guthrie & Co. 10.9.34)

F.M.S. Grants (Continued)

Year Issued	Number of Grant	Name of Grantee	Title of Invention
1934	775	Hope	An improved dryer, operated by natural draught for drying various agricultural products
1935	784	Marcene Corpn. of America	Reaction products of butadiene derivatives with hydrogen halides and method of producing the same
„	792*	Brandwood	A new or improved process and apparatus for the concentration of rubber latex
„	812	Internationale Vereeniging voor de Rubber en Andere Cultures in Ned. Indies	Improvements relating to the production of asphaltic bitumina or asphalt proper with rubber
„	815*	Dunlop Rubber Co.	Improvements in or relating to the production of concentrated India rubber latex
„	819*	Ungar and Schidrowitz	Improvements relating to the manufacture of rubber
„	824	Michelin & Cie	Improved method and apparatus for the mechanical treatment of coagulated substances preparatory to drying and transporting them
1936	827*	The Board of the Rubber Research Institute of Malaya and Eaton and Rhodes	Impovements relating to the treatment of rubber latex
„	833*	U. S. Rubber Co.	Improvements in or relating to the concentration of latex

Section 2. Registration of United Kingdom and other British Patents in F.M.S.

Year of Issue of Certificate	Number of Certificate	Number of United Kingdom Patent	Name of Grantee	Title of Invention
1933	151*	372,836	International Latex Processes Ltd.	Improvements in or relating to the production of concentrated India rubber latex
,,	152*	351,938	do.	Improvements in or relating to the manufacture of goods of rubber or similar material
1934	158*	381,743	General Rubber Co., U.S.A.	Improvements relating to the manufacture of crude rubber
,,	159*	396,579	Stam	Improved method of and apparatus for converting milky liquids, solutions, dispersions and emulsions into powder form by spray drying
,,	160*	388,341	do.	Process for the preparation of pulveriform rubber
,,	164*	393,732	Metallgesellschaft Aktiengesellschaft, and Petersen and Gensecke	Process for concentrating rubber latex
,,	171	391,031	Duarry-Serra	A process for impregnating thick textile products with latex under great hydraulic pressures
,,	172*	406,222	Cowling	Improvements in and relating to roads, side-walks, floors and like surfacings
,,	173*	409,891	do.	Improvements in and relating to roads, side-walks, floors and other surfacings
1935	179*	411,478	Imp. Chemical Ind. Ltd.	Stabilised rubber latices
,,	180*	391,511	Kaysam Syndicate Ltd.	Improvements relating to rubber or rubber-like compositions and articles manufactured therefrom
,,	181	391,853	do. do.	Improvements in or relating to the manufacture of balls or other hollow inflated articles of India rubber or the like
,,	182	391,868	do. do.	Improvements relating to rubber or rubber-like compositions and articles manufactured therefrom
,,	183	392,497	do. do.	do. do. do.

F.M.S. Registration of U.K. Patents (Continued)

Year of Issue of Certificate	Number of Certificate	Number of United Kingdom Patent	Name of Grantee	Title of Invention
1935	189*	412,514	Metallgesellschaft Aktiengesellschaft	Process of concentrating rubber latices
„	193*	429,277	Vultex Ltd.	Improvements in or relating to a process for concentrating aqueous dispersions of vulcanised rubber
„	194	429,607	do.	Improvements in or relating to the manufacture of products from rubber dispersions.
„	196*	430,426	Rubber Producers' Research Association	Improvements in and relating to the purification and concentration of latex
1936	200	433,727	The Liverpool Electric Cable Co., Ltd.	Improvements in or relating to rubber compositions and articles composed thereof
„	201	433,728	do.	do. do. do.
„	205*	437,928	Wilkinson	Improvements in or relating to the manufacture of rubber compositions from rubber latex
„	208*	429,705	Dunlop Rubber Co., Ltd.	An improved method for bonding rubber and the like to metal and other surfaces
„	209*	428,559	Dunlop Plantations Ltd.	Improved method and means for coating a metallic surface with fusible material or substance

Section 3. S.S. Grants of Exclusive Privileges 1932—1936

Year Issued	Number of Grant	Name of Grantee	Title of Invention
1931	936	General Rubber Co.	Improvements relating to the manufacture of crude rubber
„	937	Singapore Rubber Works	Improvements in water paints, distempers, colour washes and the like
1932	923	Michelin et Cie	Improvements in pneumatic tyres for railway vehicle wheels
„	927	Kirby	Improvements in and relating to latex Coagulating Tanks—Sectional Units
„	929	de Schepper	Method of and means for making and obtaining rubber in powdered form, from dispersions such as latex, or from solutions
„	931	Schweizer	A new type of partition guide and holder for coagulating tanks
„	932	do.	Improvements in and relating to Continuous Sheet Coagulating Tanks
„	938	Hughes and The Liverpool Electric Cable Co.	Improvements in or relating to Rubber Compositions and Articles composed thereof
1933	941	Reginato	Improvements in and relating to Line-Ahead Rubber Sheeting Batteries
„	944	Gaisman	Improvements in or relating to the Manufacture of Plantation Rubber Products
„	947	Naugatuck Chemical Co.	Improvements in or relating to the Treatment of Rubber Latex
„	952	do.	Improvements in or relating to Creaming of Latex
„	958	Board of the Rubber Research Institute of Malaya and Eaton	A new or improved process for the preparation of soft rubber
„	959	do.	A process for the preparation of unvulcanised India Rubber in crumb or powder form
„	961	Soc. Anon. "Septa"	Improvement in and relating to the Manufacture of Rubber Products
„	964	Kubota	Improvements in Rubber Tyres
1934	976	Reginato	Improvements in and relating to connecting troughs between the rollers of rubber sheeting machines
„	980	Dunlop Rubber Co.	Improvements in or relating to the production of concentrated India-Rubber Latex

S.S. Grants—(Continued)

Year Issued	Number of Grant	Name of Grantee	Title of Invention
1934	983	Dunlop Plantations Ltd.	Adherent Rubber Sheeting and its manufacture
1935	985	Ungar and Schidrowitz	Improvements relating to the Manufacture of Rubber
„	987	Michelin et Cie	Improved method and apparatus for the mechanical treatment of coagulated substances preparatory to drying and transporting them
„	993	United States Rubber Co.	Improvements in or relating to the concentration of latex
1936	994	Guthrie & Co., Ltd.	Improvements in and relating to Roller Adjusting Gear on Rubber Sheeting Batteries

Section 4. Registration of United Kingdom and other British Patents in S.S. 1932—1936

Year of Issue of Certificate	Number of Certificate	Number of United Kingdom Patent	Name of Grantee	Title of Invention
1932	172	309,907	Cramer	Method of Grading Planting Material of Latex-containing Trees and Tapping Tool for this purpose
„	173	363,872	Revertex Ltd.	Process for the production of Rubber-Latex concentrates
1933	179	382,235	Metallgesellschaft Aktiengesellschaft	Process for Inspissating or Concentrating Rubber Latex
„	180	383,062	Milne	Improvements relating to the Manufacture of Rubber Sheet from Coagulated Latex
„	182	383,158	Savege	Improvements in and relating to Machines for Rolling Coagulated Latex and like Materials
„	186	391,735	Vis	Method of Tapping Rubber Trees and such-like sap-containing trees
„	187	372,836	International Latex Processes Ltd.	Improvements in or relating to the production of Concentrated india-rubber latex
„	189	388,341	Stam	Process for the Preparation of Pulveriform Rubber
„	190	396,579	do.	Improved method of and Apparatus for converting Milky Liquids, Solutions, Dispersions and Emulsions into Powder Form By Spray Drying
„	193	393,732	Metallgesellschaft Aktiengesellschaft, and Petersen and Gensecke	Process for Concentrating Rubber Latex
1934	200	351,988	International Latex Processes Ltd. (assignees of Dunlop R.C. & others)	Improvements in or relating to the manufacture of goods of rubber or similar material
„	203	391,031	Duarry-Serra	A process for impregnating thick textile products with latex under great hydraulic pressures
„	204	406,222	Cowling	Improvements in and relating to Roads, Sidewalks, Floors and like surfacings

S.S. Registration of U.K. Patents (Continued)

Year of Issue of Certificate	Number of Certificate	Number of United Kingdom Patent	Name of Grantee	Title of Invention
1934	205	409,891	Cowling	Improvements in and relating to Roads, Sidewalks, Floors and other surfacings
1935	213	391,853	Kaysam Syndicate Ltd.	Improvements in or relating to the manufacture of balls or other hollow inflated articles of India Rubber or the like
„	214	392,497	do.	Improvements relating to Rubber or Rubber-like Compositions and articles manufactured therefrom
„	215	391,868	do.	do. do.
„	216	391,511	do.	do. do.
„	221	412,514	Metallgesellschaft Aktiengesellschaft	Process for Concentrating Rubber Latices
„	230	429,277	Vultex Ltd	Improvements in or relating to a Process for concentrating Aqueous Dispersions of Vulcanised Rubber
„	231	429,607	do.	Improvements in or relating to the manufacture of Products from Rubber Dispersions
„	234	430.426	Rubber Producers' Research Association	Improvements in and relating to the Purification and Concentration of Latex
1936	236	433,728	Liverpool Electric Cable Co.	Improvements in or relating to Rubber Compositions and articles composed thereof
„	237	433,727	do.	do.
„	241	437,928	Wilkinson	Improvements in or relating to the Manufacture of Rubber Compositions from Rubber Latex
„	242	429,705	Dunlop Rubber Co.	An improved method for Bonding Rubber and the like to Metal and other surfaces

The abstracts of selected patents are set out in the following broad general groups of subject matter :—

Group No.	General Heading	Number of patents in group
I	Concentration of latex	12
II	Powdered, crumb, and soft rubbers	7
III	Manufacturing processes based on latex and rubber	5
IV	Rubber estate equipment	9
V	Rubber Roadways	3
VI	Miscellaneous	1

Group I

Concentration of Latex

(1) International Latex Processes Ltd.
British Patent No. 372,836; 1931
Registered in F.M.S. No. 151; 1933
Improvements in or relating to the Production of Concentrated India Rubber Latex

Concentrated latex preserved with a caustic alkali (or some similar preservative) is obtained by centrifuging ordinary latex preserved with ammonia, then adding the desired caustic alkali to the concentrate thus obtained and heating to remove the residual ammonia. Latex concentrated in this way contains a smaller proportion of non-caoutchouc constituents than latex which has been concentrated entirely by evaporation.

(2) Dunlop Rubber Co., Ltd.
F.M.S. Grant No. 815, 1935
Improvements in or relating to the Production of Concentrated India Rubber Latex

Describes a method of increasing the efficiency of the centrifugal process of concentration, by heating the latex and centrifuging it at a temperature between 45° C and 85°C. A greater proportion of the total rubber is obtained as cream, but the dry-rubber-content of this cream might be lower (as in some of the examples given in the patent specification) than if the centrifuging had been done at ordinary temperatures.

(3) Vultex Corporation
British Patent No. 429,277; 1933
Registered in F.M.S. No. 193; 1935
Improvements in or relating to a Process for concentrating Aqueous Dispersions of Vulcanised Rubber

The proteins and other non-caoutchouc constituents of latex are aids to vulcanisation. This fact is made use of in this process for preparing concentrated *vulcanised* latex by vulcanising first and removing the proteins etc. afterwards. Ordinary preserved latex is treated with vulcanising agents and is then centrifuged. The centrifuging gives a concentrate (cream) which contains a lower proportion of non-caoutchouc serum constituents than the original latex, as the greater part of these passes into the skim. This cream can be washed by diluting with ammoniated water and centrifuging again, repeating the process several times if required, and in this way a vulcanised concentrated latex free from non-

caoutchouc serum constituents is finally obtained. This product is stable and can be transported long distances without coagulating.

British Patent No. 429,607, registered in F.M.S. No. 194, 1935, describes methods of making various rubber articles by the heat coagulation on formers of vulcanised concentrated latex prepared as above.

(4) Naugatuck Chemical Co.
F.M.S. Grant No. 758, 1933
Improvements in or relating to the Treatment and Creaming of Rubber Latex

Describes a method of accelerating the process of creaming latex, by the use of a small quantity of water soluble soap (about 0.3 per cent) in addition to the usual creaming agents such as karaya gum, ammonium alginate, etc.

(Patent assigned to United States Rubber Co. in 1935).

(5) Naugatuck Chemical Co.
F.M.S. Grant No. 768, 1934
Improvements in or relating to Creaming of Latex

Creaming is accelerated by violently agitating the latex, as with a high speed mechanical stirrer, for a short time before, after, or simultaneously with the addition of the creaming agent. If desired, the latex may be vulcanised before it is agitated.

(Patent assigned to United States Rubber Co. in 1935).

(6) General Rubber Co.
British Patent No. 381,743; 1931
Registered in F.M.S. No. 158; 1934
Improvements relating to the Manufacture of Crude Rubber

Describes a method of making crude rubber containing any desired proportion, from about 12 per cent to 80 per cent, of non caoutchouc latex constituents. The process consists of separating latex into cream and skim, and then recovering crude rubber from the skim by evaporation, *e.g.* by spray drying. The proportion of non-caoutchouc constituents in the crude rubber thus obtained depends on the extent to which the separation of the original latex into cream and skim had been carried out, and is therefore controllable. The rubber obtained by these means has such properties as tensile strength, tear resistance, and age resistance enhanced, by which its value for certain purposes is increased.

(7) J. Brandwood
F.M.S. Grant No. 792, 1935
A new or improved Process and Apparatus for the Concentration of Rubber Latex

A process for accelerating creaming by imparting to the latex mechanical vibratory impulses, in addition to using a creaming agent such as gum tragacanth in glycerine.

(8) Board of the Rubber Research Institute of Malaya and B. J. Eaton and E. Rhodes
F.M.S. Grant No. 827, 1936
Improvements relating to the Treatment of Rubber Latex

This patent was first taken out in the United Kingdom, as British Patent No. 415,133. It is published in full in the *Journal of the Rubber Research Institute of Malaya*, Volume 6, No. 2, December 1935, page 137.

The creaming of latex by means of an organic colloid such as gum tragacanth is accelerated by the addition of a small proportion of a neutral organic liquid which is more volatile than water; *e.g.* ethyl alcohol or acetone may be added at the rate of about 2 to 5 per cent by volume of the original latex and results in more rapid creaming and in a richer final cream.

(9) United States Rubber Co.
F.M.S. Grant No. 833, 1936
Improvements in or relating to the Concentration of Latex

The rate at which latex creams becomes slower as the creaming proceeds. In preparing very pure rubber, latex may be creamed several times; *i.e.* it is creamed, and then the cream separated, diluted with water, and allowed to cream again; and so on. The time required for this can be shortened by interrupting each successive creaming at the point where the rate of creaming is decreasing rapidly, which might occur after about one quarter of the time normally required for complete creaming has elapsed. The last of the re-creaming operations is of course allowed to proceed to its finish.

This process may be used in conjunction with other methods for accelerating creaming, *e.g.* violent agitation of the latex, the addition of other chemicals besides the creaming agent, etc., etc.

(10) Rubber Producers' Research Association
British Patent No. 430,426; 1934
Registered in F.M.S. No. 196; 1935
Improvements in and relating to the Purification and Concentration of Latex

The purification and concentration of latex are carried out simultaneously or consecutively by dialysis under pressure. The apparatus consists essentially of a series of cells separated by

dialysing membranes. Alternate cells are charged with ammoniated latex and the intermediate cells contain water or an aqueous solution of some substance such as an ammonium soap. The latex cells are under a hydrostatic pressure of 1 to 2 lb. per square inch more than the intermediate cells. The carbohydrates, salts, etc. contained in the latex pass by dialysis through the membranes into the water or solution in the intermediate cells, and the corresponding dilution of the latex which would normally occur is retarded or reversed by the greater pressure in the latex cells, aided by the osmotic action of the aqueous solution if such is used. The ammonia content of the latex requires to be renewed from time to time during the working of the process.

Variations of this process are the hydrolysis of the non-caoutchouc constituents by heat before dialysis, and the concentration of the latex before and/or after dialysis by means of evaporation, centrifuging, creaming, or spray drying.

(11) Metallgesellschaft Aktiengesellschaft and Petersen and Gensecke
British Patent No. 393,732; 1932
Registered in F.M.S. No. 164; 1934
Process for Concentrating Rubber Latex

A quantity of stabilised latex is circulated through a system in which it is alternately heated and then discharged into an evaporation chamber under reduced pressure. The water vapour formed in the evaporation chamber is withdrawn and condensed separately. When the latex has become sufficiently concentrated the circulation is stopped and the concentrate run off, after which another charge of latex is admitted to the system and the circulation resumed. Owing to the increase in the viscosity of the latex as concentration proceeds, the process is more conveniently worked in two or more stages.

(12) Metallgesellschaft Aktiengesellschaft
British Patent No. 412,514; 1934
Registered in F.M.S. No. 189; 1935
Process for Concentrating Rubber Latices

Describes a process for obtaining concentrated latex which is wholly or partially free from serum constituents. The method is to take latex which has already been concentrated by creaming or centrifuging, and has thus lost some of its serum constituents, and then to concentrate it further by some evaporation process such as that described under B.P. No. 393,732 (see above). The final product contains more than 65 per cent of total solid , is free from included air, and has a reduced proportion of non-caoutchouc constituents.

Group II

Powdered, Crumb, and Soft Rubbers

(1) A. J. A. Yssel de Schepper
F.M.S. Grant No. 727, 1933
Method of and means for making and obtaining Rubber in Powdered form, from Dispersions such as Latex, or from Solutions

Latex or rubber solution is sprayed on to a moving surface, such as a rotating drum, where it is dried by heat and then mechanically scraped off in the form of a powder. The process is continuous. The latex or rubber solution can be treated with compounding and vulcanising materials etc. before spraying, so that the resulting rubber powder is ready for use in manufacture without further compounding. Where this has not been done, and further compounding is necessary, the powdered rubber can be mixed much more easily than ordinary forms of rubber such as sheet and crepe.

(2) M. J. Stam
British Patent No. 396,579; 1932
Registered in F.M.S. No. 159; 1934
Improved Method of and Apparatus for Converting Milky Liquids, Solutions, Dispersions and Emulsions into Powder form by spray drying

The liquid, *e.g.* latex, is sprayed from a centrifugal sprayer and is carried upwards by a forced draught which dries the substance besides carrying it upwards and out of the spraying chamber. The spraying chamber is of special shape, and the forced draught is regulated according to the rate at which the liquid is sprayed. After leaving the spraying chamber the stream of air and sprayed substance is forced into a filtration chamber where the air and water vapour are drawn out and the dried residue falls downwards as a powder on to a conveyor which carries it to an outlet.

(3) M. J. Stam
British Patent No. 388,341; 1932
Registered in F.M.S. No. 160; 1934
Process for the Preparation of Pulveriform Rubber

Describes the use of dextrin (6 to 12 per cent on the latex) as a protective colloid to be added to latex so that when the latter is spray-dried a non-sticky powder is obtained.

(4) Board of the Rubber Research Institute of Malaya and B. J. Eaton
F.M.S. Grant No. 744, 1933
Process for the Preparation of Unvulcanised India-rubber in Crumb or Powder form

Rubber latex is treated with a salt of nitrous acid, *e.g.* 1 per cent or more by weight of sodium nitrite, followed by sufficient acid to produce coagulation and also to react with all the nitrite present. A spongy coagulum is obtained which is washed and then is easily disintegrated into powder. This powder or crumb rubber can be dried in the air in about two days. Its use in the manufacture of rubber goods would facilitate mixing operations.

(5) Board of the Rubber Research Institute of Malaya and B. J. Eaton
F.M.S. Grant No. 743, 1933
A new or improved Process for the Preparation of Soft Rubber

Rubber latex is treated with a salt of nitrous acid, *e.g.* sodium nitrite, followed by coagulation with an acid, *e.g.* formic or acetic acid. The nitrous acid liberated from the nitrite reacts to give a plastic rubber in the form of a porous coagulum, which after machining and drying is softer than crepe or sheet and can be used to facilitate manufacturing operations. Fresh, preserved, or artificial latex, concentrated or diluted, may be used for the process. The reaction may be accelerated by heating if desired.

(6) L. Gaisman
F.M.S. Grant No. 746, 1933
Improvements in or relating to the Manufacture of Plantation Rubber Products

A process for making on the plantation rubber having plasticity, softness, and other qualities which make it equivalent to "reclaimed rubber," thus increasing its value for many manufacturing purposes. The necessary ingredients such as mineral or vegetable oils are added to the latex, either in the form of an emulsion, or direct, and the whole coagulated, machined, and dried in the usual way.

(7) R. W. Ungar and P. Schidrowitz
F.M.S. Grant No. 819, 1935
Improvements relating to the Manufacture of Rubber

In a previous patent, British Patent No. 368,902, the preparation of softened rubber by the controlled oxidation of crude rubber such as sheet or crepe was described. The present patent is an extension of this process so as to prepare softened rubber direct

from coagulum. The method is to break up the coagulum into crumbs, wash thoroughly, and dry on trays in a steam oven at 270° —290°F. with dry steam circulating at a pressure of 100 pounds per square inch. When the crumb is dry, air is admitted into the oven for from 10 to 30 minutes according to the degree of softness required in the finished product, with dry steam continuing to circulate as previously. The trays of heated, oxidised rubber are then taken out and allowed to cool in the air, after which the rubber may be agglomerated for packing.

Group III

Manufacturing Processes based on Latex and Rubber

(1) Société Anonyme Septa
F.M.S. Grant No. 762, 1933
Improvements in and relating to the Manufacture of Rubber Products

Describes a method for the manufacture of soft rubber products direct from latex combined with fibrous, porous, or granular reinforcing material. Latex is spread upon a plate, impressed with the desired grooves or pattern, and allowed to dry. Then the reinforcing material is applied to the surface of the rubber sheet thus formed, latex itself being used as a binding agent. Paper or cloth or granular substances can be used as the reinforcing material, and articles can be made consisting of two layers of soft rubber with an intermediate reinforcing layer, the whole being united integrally by means of the latex.

(2) International Latex Processes Ltd.
British Patent No. 351,938; 1930
Registered in F.M.S. No. 152; 1933
Improvements in or relating to the Manufacture of goods of Rubber or similar material

Describes a process for the manufacture of crumb-like or powder-like compositions of rubber or similar material from aqueous dispersions thereof, *e.g.* latex, by the addition of such substances as ground tyre carcases, wood flour, leather dust etc. The process is in two stages. The compounding ingredients, with protective colloids, are first added to the aqueous rubber dispersion, followed by the ingredients mentioned above. Then this mixture is coagulated by the addition of some substance such as zinc oxide or lime, previously made into a paste with water. The result is a crumb-like composition which can be moulded whilst wet, or which can be dried and worked on the ordinary rubber machinery.

(3) Kaysam Syndicate Ltd.
British Patent No. 391,511; 1932
Registered in F.M.S. No. 180; 1935
Improvements relating to Rubber or Rubber-like Compositions and Articles manufactured therefrom

Describes a method of making moulded rubber goods from aqueous dispersions of rubber, *e.g.* latex. First a stable mix is made containing the necessary fillers, vulcanising agents, etc. Then the mix is rendered unstable by the addition of a "setting" agent, such as ammonium nitrate. This does not cause immediate coagulation and the mix can be poured into a mould, where it thickens and sets. In order to obtain a quick setting, the mould should be heated to 80°—90°C. If cold setting is desired, a higher proportion of setting agent is used. Such articles as rubber heels can be made in this way, and any metal parts, e.g. washers, can be embedded in the rubber by placing them on supports in the mould before pouring in the mix.

British Patents Nos. 391,853; 391,868; and 392,497; registered in the F.M.S. Nos. 181, 182 and 183 respectively, deal with particular applications of the above general patent.

(4) B. Wilkinson
British Patent No. 437,928; 1935
Registered in F.M.S. No. 205; 1936
Improvements in or relating to the Manufacture of Rubber Compositions from Rubber Latex

A vulcanising agent, such as sulphur, and an accelerator, are mixed with the latex which is then coagulated. The coagulum is machined into sheet or crepe, and dried. Vulcanisation preferably takes place during storage at atmospheric temperature, the amount and type of accelerator used being such that little or no vulcanisation occurs before or during drying. Complete vulcanisation may take from one or two weeks to several months. If desired the sheet or crepe can be dried at 80° to 120°F., and the subsequent vulcanisation can be hastened by storing the product at the same temperature. Fillers, colouring materials, etc., can be mixed with the latex before coagulation.

(5) Dunlop Rubber Co.
British Patent No. 429,705; 1935
Registered in F.M.S. No. 208; 1936
An improved Method for bonding Rubber and the like to Metal and other Surfaces

The method consists essentially of treating the surface of the rubber with strong sulphuric acid and pressing it against the prepared

surface of the rigid material where it is held under pressure for at least 10 minutes at 148°C. Further heat treatment might be necessary to complete the vulcanisation of the rubber, if this had not been done previously. If the rubber surface contains any grease, oil, etc. it is prepared by treating with a saturated solution of chromium tri-oxide in sulphuric acid. The metal surface must be freed from grease, scale, rust etc. before applying the treated rubber surface.

Applications of this method are found in the manufacture of rubber-lined pipes, tanks, floor boards, etc.

Group IV

(1) H. Schweizer
F.M.S. Grant No. 724, 1932
A new type of Partition Guide and Holder for Coagulating Tanks

Instead of having grooves in the sides of coagulation tanks, the sides and/or bottoms of the tanks are embossed so that the partitions are held in place by the protrusions thus formed. Where the tanks are made of material which cannot be embossed, beadings or mouldings are fastened to the sides and/or bottoms to serve the same purpose. Such tanks, being without grooves, are more easily cleaned during use and are also more easily made.

(2) H. Schweizer
F.M.S. Grant No. 725, 1932
Improvements in and relating to Continuous Sheet Coagulating Tanks

The coagulating tanks are fitted with corrugated sides, instead of straight sides, so that the bend in the continuous coagulum is curved instead of being rectangular. This prevents thick and uneven patches in the resulting continuous sheet. The partitions have suitable beadings which fit into the corrugations. In this way the partitions are held rigidly in place.

(3) Sime, Darby & Co.
F.M.S. Grant No. 729, 1933
Improvements in and relating to Latex Coagulating Tanks

Describes a coagulating tank with corrugated sides, so that continuous coagulum of uniform thickness can be made. The partitions, suitably cut, are held in place by slots in reinforced constructions extending throughout the length of the tank and above the corrugations in the sides. It is claimed that in addition to such tanks being

suitable for making uniform continuous coagulum, the corrugations on the sides confer great strength. Hence such tanks can be made of relatively thinner material, reinforced at top and bottom only.

(4) G. B. Reginato
F.M.S. Grant No. 733, 1933
Improvements in and relating to Line-ahead Rubber Sheeting Batteries

Describes the "Reginato" flat-faced rolls, used for the first pair of rolls in the battery and for other rolls if desired. Also describes the use of floating or "jockey" rollers, placed between the different pairs of rolls on the battery for the purpose of keeping the continuous coagulum at the proper tension.

(5) J. Cochran and C. C. Footner
F.M.S. Grant No. 757, 1933
An improved Machine for the Rolling of Coagulated Latex

The machine has five pairs of rolls of varying diameters placed close together in two groups running at different shaft speeds. An adjustable guide is fitted to keep the sheets straight and there is also an arrangement for raising all the top rolls simultaneously when it is necessary to remove sheet which has stuck. The machine, including its engine if one is used, can be mounted on wheels enabling it to be moved as desired.

(6) G. B. Reginato
F.M.S. Grant No. 772, 1934
Improvements in and relating to Connecting Troughs between the Rollers of Rubber Sheeting Machines

Describes an automatic chute for conveying sheet from one pair of rollers to the next, without requiring a person to move or guide the sheet. The chute is pivoted and controlled by springs, and is fitted with a self-centring device consisting of small wheels inserted into its surface and arranged in herring-bone fashion.

(7) Socfin Company Limited
F.M.S. Grant No. 737, 1933
Drying and/or Smoking Plant

Describes the well known "Socfin" dryer and/or smoke house, by means of which sheet rubber of suitable thinness is dried in less than 48 hours. Drying is in three stages:—(1) a few hours of dripping under shade, (2) almost one day in a well-ventilated chamber heated to 100°—120° F., and (3) almost one day in a closed chamber

at a higher temperature. The chambers can be heated by steam pipes, and smoke generated in smoke pots can be admitted if desired. The design of the building is such that the risk of fire is greatly reduced.

(8) E. W. Savege
F.M.S. Grant No. 770, 1934
Improvements in and relating to Presses for Packing Rubber and the like

Describes a press fitted with hinged side pieces. These prevent lateral bulging of the packed case when pressure is applied.

(9) Dunlop Plantations Ltd.
British Patent No. 428,559; 1934
Registered in F.M.S. No. 209; 1936
Improved Method and Means for Coating a Metallic Surface with Fusible Material or Substance

A container, such as a latex drum, can be given an internal protective coating by spraying it on the inside with fused substance, such as molten wax, which is in this way deposited as a powder on the interior surface. To form a continuous protective film of wax, the sprayed drum is closed and rotated in a bath of hot water. This melts the wax, giving a continuous liquid film which solidifies when the drum is allowed to cool. When the drum is being rotated under water it can at the same time be tested for leaks. In treating a large surface, such as a ship's tank, it is sprayed with the molten wax, and the deposit thus formed is then converted into a continuous film by rapidly playing over it the flame of a blow lamp.

Group V

RUBBER ROADWAYS

(1) D. Graham & R. W. Kendall
F.M.S. Grant No. 726, 1932
Rubber Road Carpeting

A road surfacing material consisting of slabs or strips of vulcanised rubber compound. The slabs should be three or more feet wide, of a length according to the width of the road, and from one to three and a half inches thick according to the volume and nature of the traffic. The slabs are laid on the road in hot asphalt, which is also used to caulk the joins.

(2) H. W. Cowling
British Patent No. 406,222; 1933
Registered in F.M.S. No. 172; 1934
Improvements in and relating to Roads, Sidewalks, Floors and like Surfacings

Describes a process of applying a rubber latex composition to a road or similar surface. The underlayer on which the composition is to be laid must be dry and its surface must contain depressions to help to hold the composition. After applying an adhesive to the underlayer the latex composition is poured on as a paste and becomes set and vulcanised under ordinary atmospheric conditions. If desired the rubber surface can be reinforced by such reinforcing material as galvanised iron wire netting, which is fixed to the underlayer before pouring on the latex composition. After the composition has set, it can be consolidated by rolling.

(3) H. W. Cowling
British Patent No. 409,891; 1933
Registered in F.M.S. No. 173; 1934
Improvements in and relating to Roads, Sidewalks, Floors, and other Surfacings

Describes an improved rubber latex composition for making roads etc. Besides the usual compounding and vulcanising ingredients, this composition contains a flocculating agent, such as lime, so that on setting the surface will dry evenly without cracking. This rubber latex composition can be preserved by the addition of casein, or some similar substance, and can then be packed in drums for transport. Also, if desired, part of the water can be removed by evaporation or by centrifuging, the composition being thinned down again before use if necessary.

Group VI

MISCELLANEOUS

(1) Imperial Chemical Industries Ltd.
British Patent No. 411,478; 1932
Registered in F.M.S. No. 179; 1935
Stabilised Rubber Latices

Describes the production of stable rubber latex by adding to fresh or concentrated latex a compound of the class R. O. SO^3 M,

where R is an aliphatic hydrocarbon radical containing an alkyl chain of not less than 10 carbon atoms and M is hydrogen, an alkali metal, ammonium or alkyl ammonium.

Literature Cited.

(1) Wiltshire, J. L. *J.R.R.I.M.* **5** (1933) 48

(2) Rhodes, E. & Wiltshire, J. L. *J.R.R.I.M.* **5** (1934) 196

Kuala Lumpur,
12th January, 1937

PLANTING HOLES AND THE BREEDING OF MOSQUITOES

The Malaria Advisory Board invites the attention of Planters to the danger to health likely to arise during the replanting of rubber, from the breeding of anopheline mosquitoes in pits left by the uprooting of trees and in holes prepared for replanting. Care should be taken to avoid the accumulation of water in such places, within half-a-mile of houses, as they may rapidly become the source of large numbers of *Anopheles maculatus* and other malaria-carrying mosquitoes.

Pits left by the uprooting of old trees should be filled up immediately. It is suggested that holes prepared for replanting, which are likely to become a source of mosquito breeding, should be kept *filled* with cut vegetation. Planting should, however, be undertaken as early as possible.

When fresh clearings are made care should be taken to avoid felling trees across ravines, as the fallen trees prevent access by oiling coolies to streams and drains. Where clearing is done on contract it may be necessary to insert a clause to this effect in the contract.